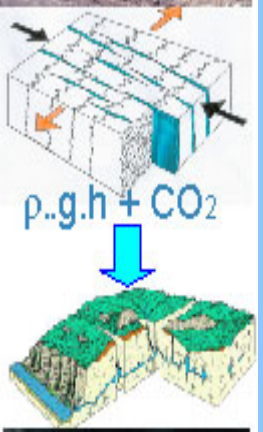
AXE 2

HydroSciences Montpellier



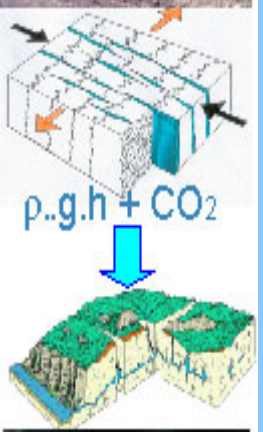
Karst Sub-Marine Springs (KSMS)

Michel BAKALOWICZ

HydroSciences, CNRS and CREEN-ESIB

AXE 2

HydroSciences Montpellier

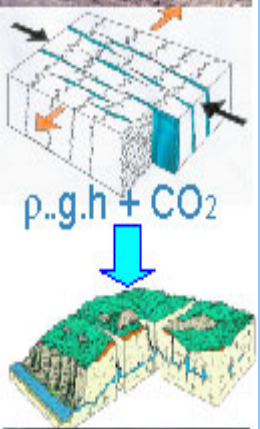


Why do KSMS exist?

- Because the sea level was below the present sea level:
  - During Quaternary, for the global ocean, at -100 to -150 m during glaciations
  - During the Messinian salinity crisis (-5.5 Ma), only in the Mediterranean basin, at -1000 to -1500 m

AXE 2

HydroSciences Montpellier



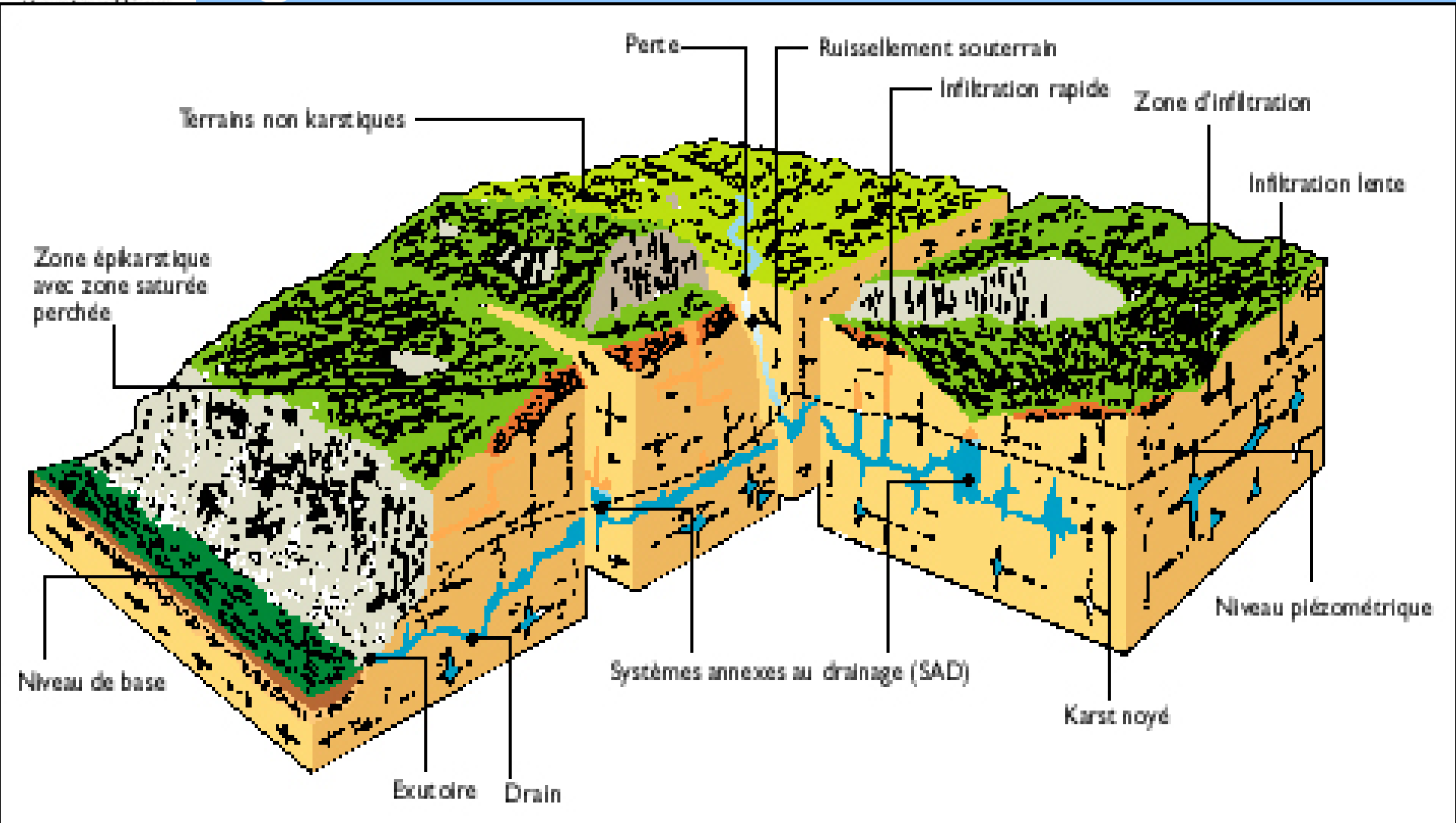
Why do KSMS exist? Cont'

- Low sea levels give to groundwater flows low base levels, allowing to karst processes developing conduits at depth in carbonate aquifers

AXE 2

HydroSciences

The karst conduit network in agreement with its base level…



AXE 2

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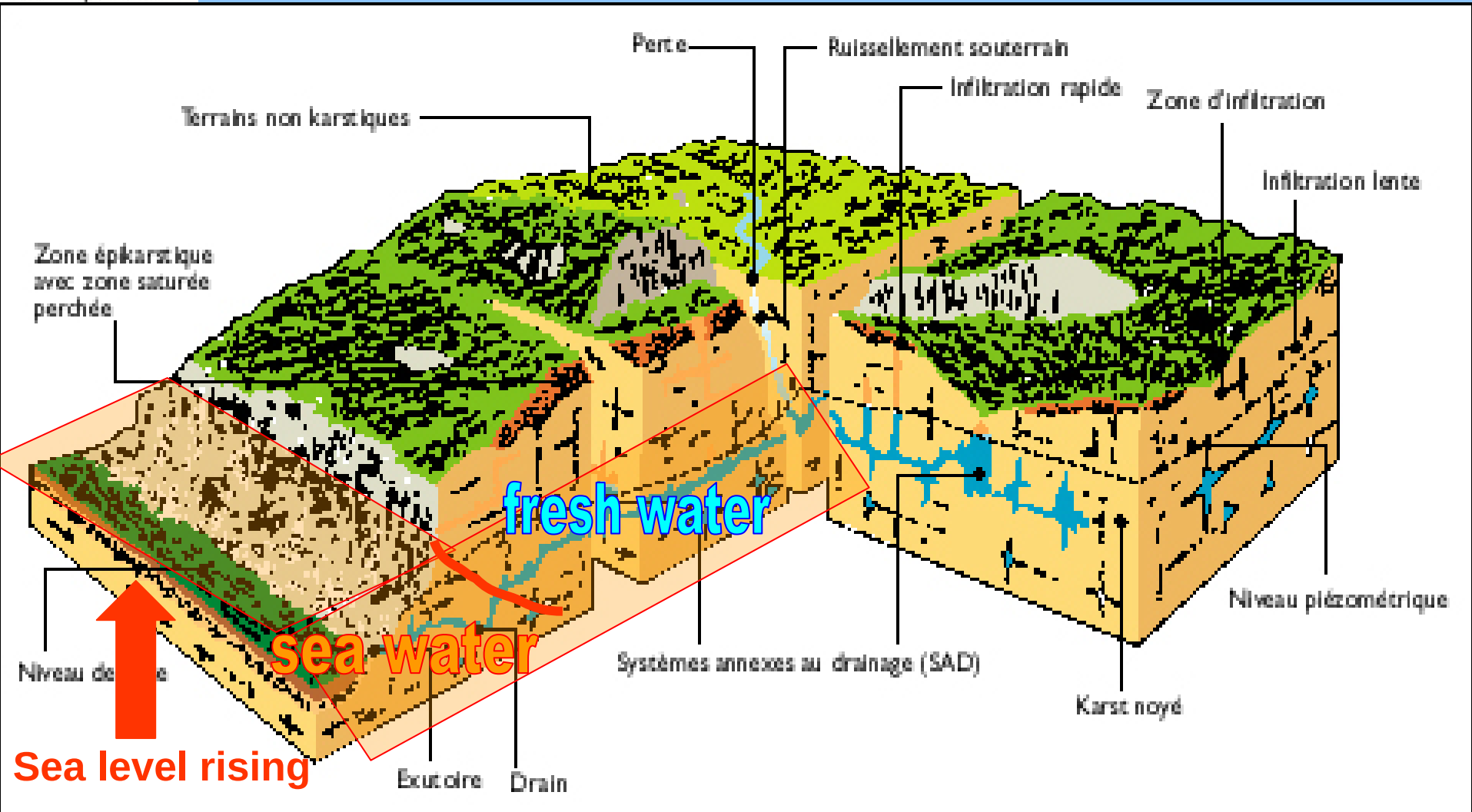
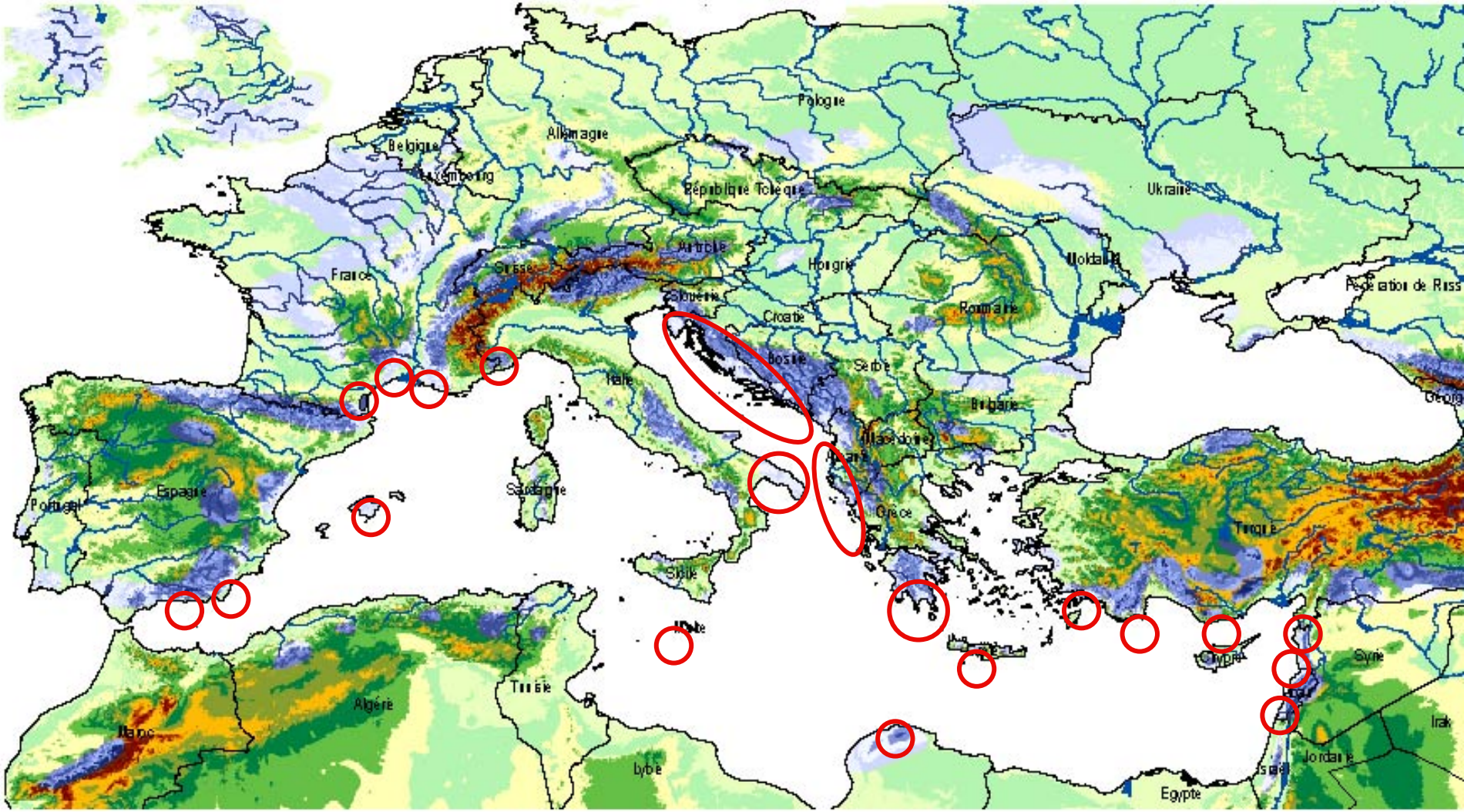
… and after the rising of sea level



AXE 2

KSMS around the Mediterranean



Mediterranean coastal karsts

AXE 2

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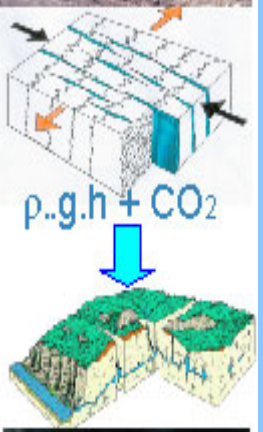

The KSMS in Chekka Bay, Lebanon, in october (low stage flow)

AXE 2

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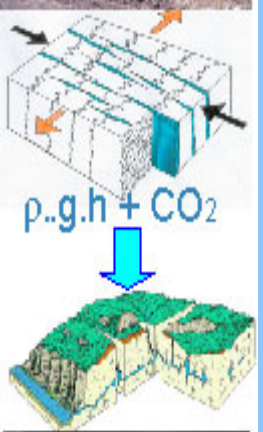
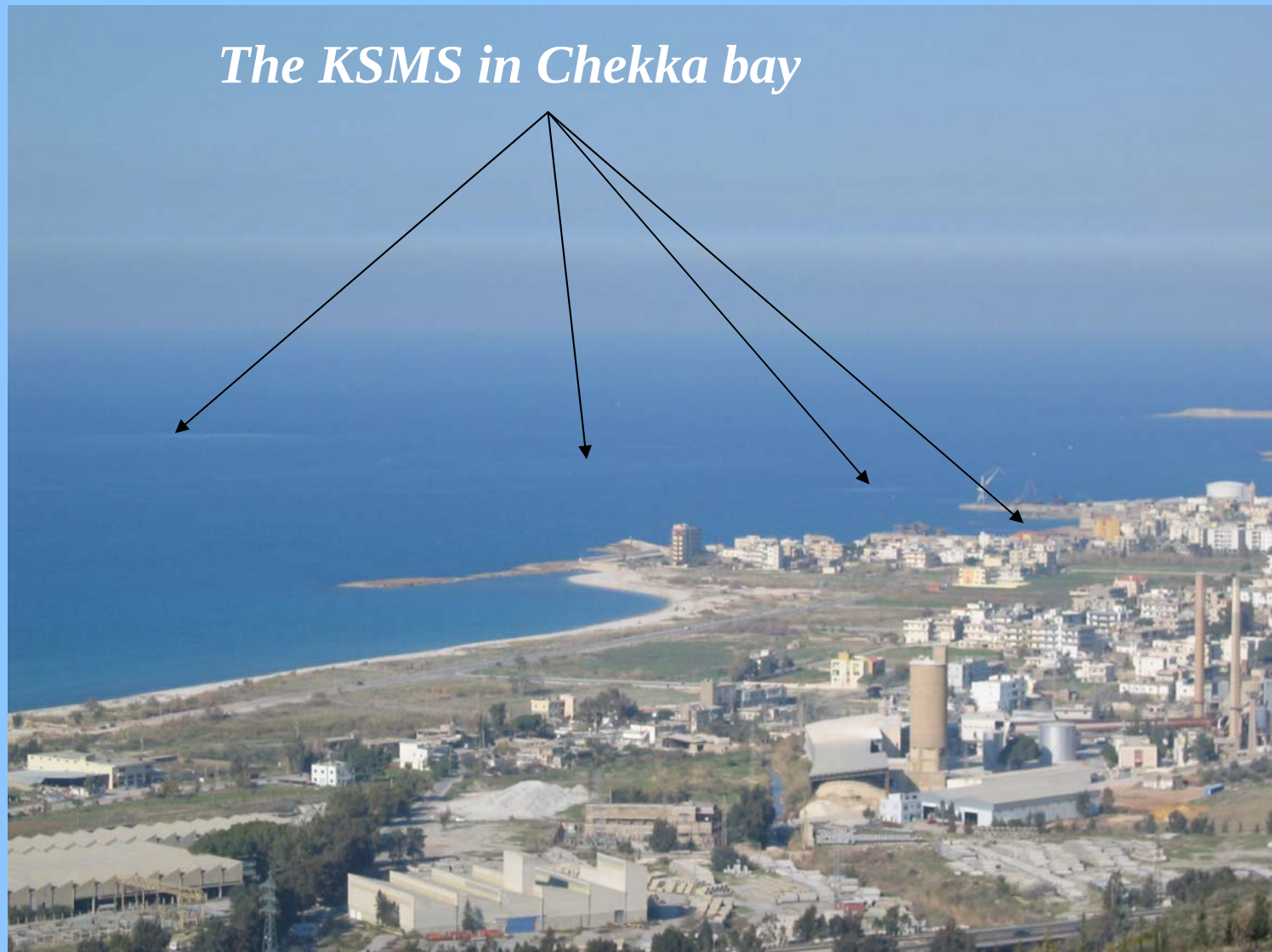


The KSMS in Chekka Bay, Lebanon, in december (flood regime)



AXE 2

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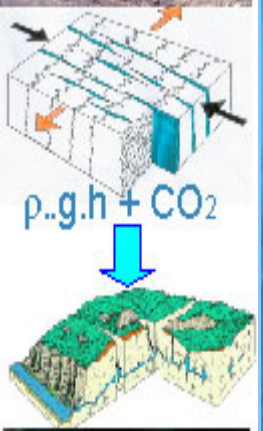
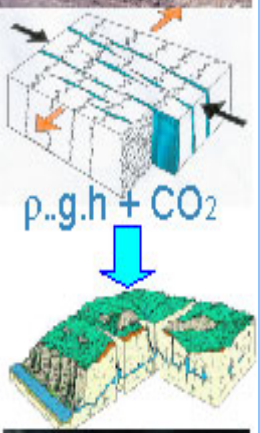


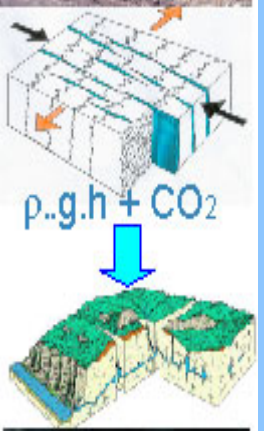
AXE 2

HydroSciences Montpellier



AXE 2

HydroSciences Montpellier



Why should we take an interest in KSMS?

- Their assessment is necessary :
  - In hydrological balances
  - For controlling the impacts of pumping in coastal aquifers
- They are a potential groundwater resource in regions with poor resource

AXE 2

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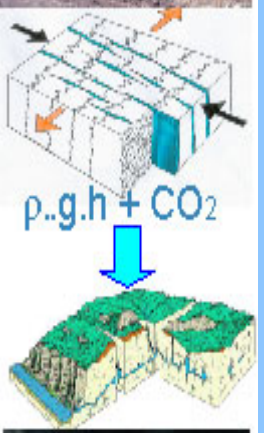

Why should we prefer control and tapping of KSMS to on-shore wells?

- Boreholes are hazardous in karst, so that they are not representative of the aquifer functioning
- Best chances are close to karst springs
- Flow at karst outlets must be monitored in quantity and quality for surveying man and climate impacts for a sustainable management of water resources

AXE 2

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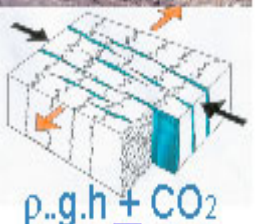

How can we display KSMS?

- By local investigations
- By means of remote sensing
- By direct exploration
  - by divers : difficult and not really reliable
  - from a boat : requiring important measures and a long time

AXE 2

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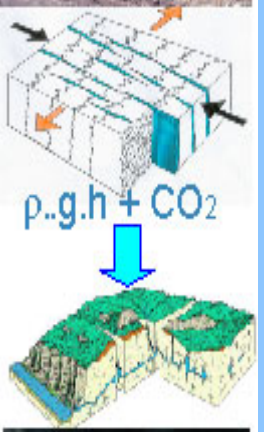

Reliability of field investigations

- Good knowledge about the existence and location of KSMS
- Results not easy to interpret from remote sensing (2D picture of the sea surface for a 3D phenomenon, the fresh water plume)
- Lowly reliable information from divers about flow rates and fresh water quality (overestimation because of mixing and of wrong integration of flow velocity)

☞ **NO POSSIBLE QUANTIFICATION OF KSMS!**

AXE 2

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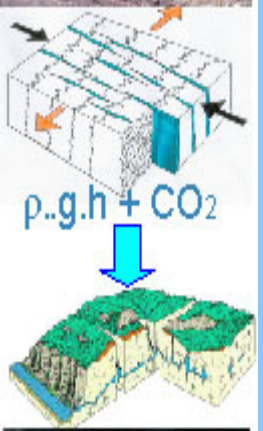

Investigations from a boat

- Mapping the fresh water plume from temperature and salinity measurements and from samples
- What is necessary : a boat + 1 or 2 seamen + 2 to 4 scientists with a multiparameter probe and sampling bottles

AXE 2

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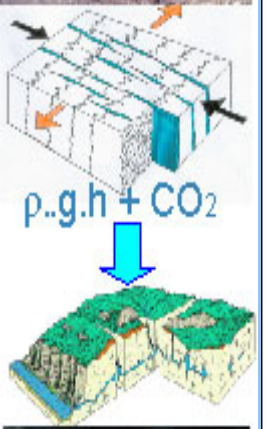
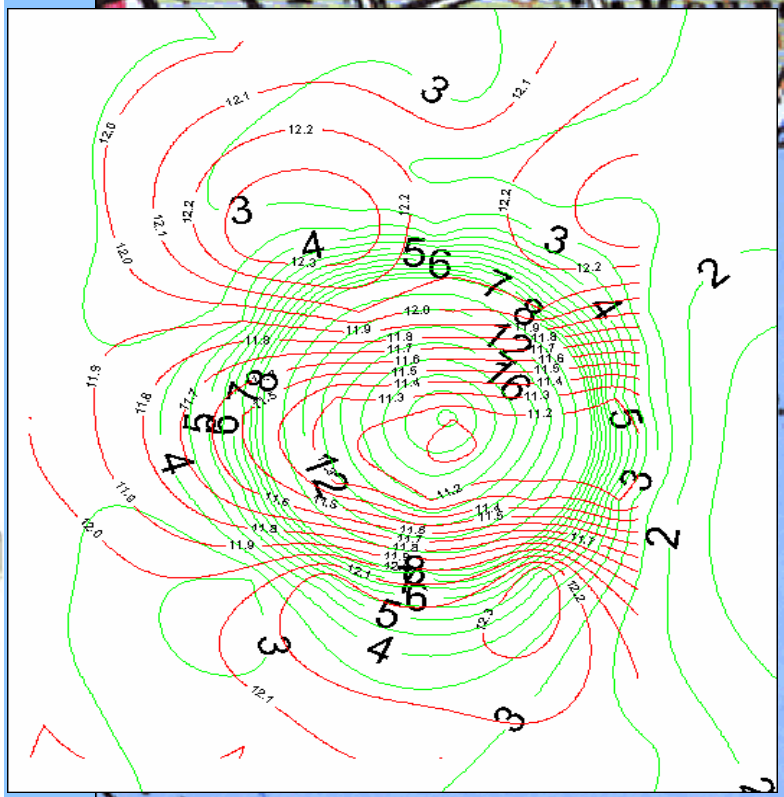
Mapping the freshwater plume in Thau lagoon from a boat…





Isotemperatures at a 3 m depth

AXE 2

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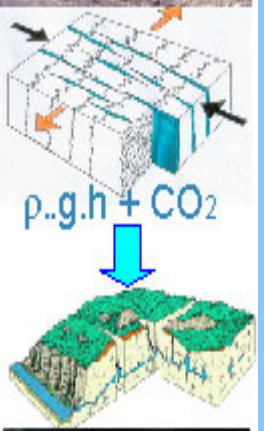

… and problems !

- For one field campaign, i.e. one flow rate estimate, 3 working days…
  - after several months waiting for good conditions, the boat and men, nice weather, no wind…
- only 2 experiments within 3 years!
- sampling step between 25 and 250 m

AXE 2

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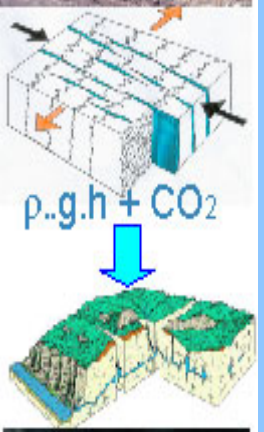

How do we use the data?

- The freshwater plume is build in 3D from the temperature, salinity and flow velocity fields
- Knowing the bathymetry and spring depth, the plume is modeled for different flow rates
- Then the simulated and observed plumes are compared for assessing the flow rate.

AXE 2

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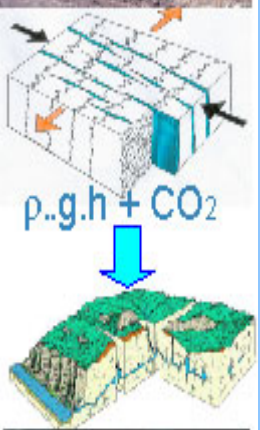


Proposed approach :

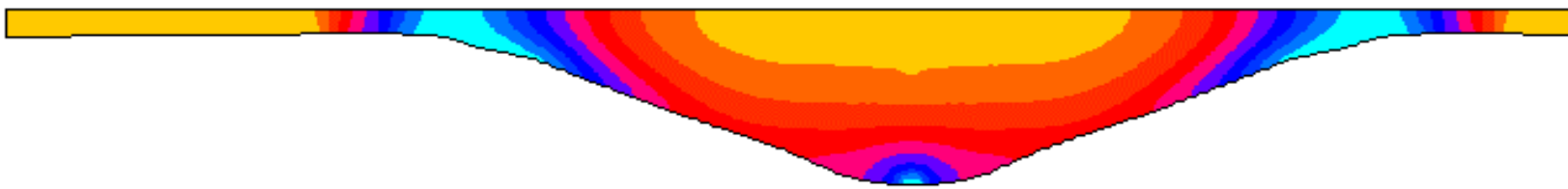
• from the bathymetry, a model simulates the velocity, temperature and salinity fields for several flow rates (from 50 to 1000 L/s).

Comparison of simulated vs observed plume :

QKSMS < 100 L/s

Evaluations by divers and direct flow measurement :

about 1000 L/s



AXE 2

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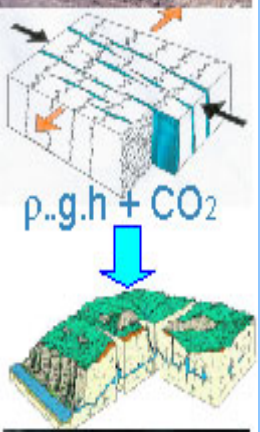

Therefore we had got the idea of developing an Autonomous Underwater Vehicle (AUV) for exploring a KSMS freshwater plume rapidly and repeating the acquisition of data

AXE 2

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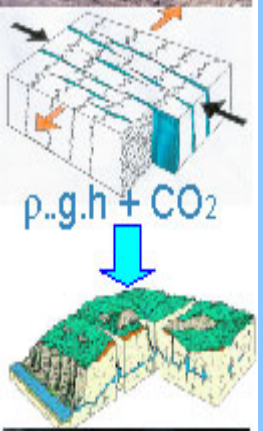

Tasks prescribed to the AUV

- To control and record the trajectory
- To measure water temperature and salinity
- To measure the velocity field
- To take pictures of the plume

AXE 2

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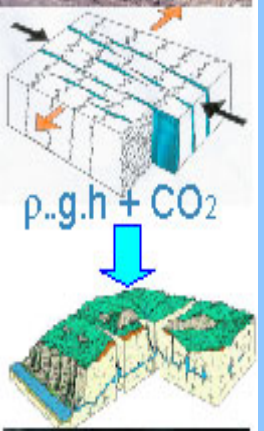
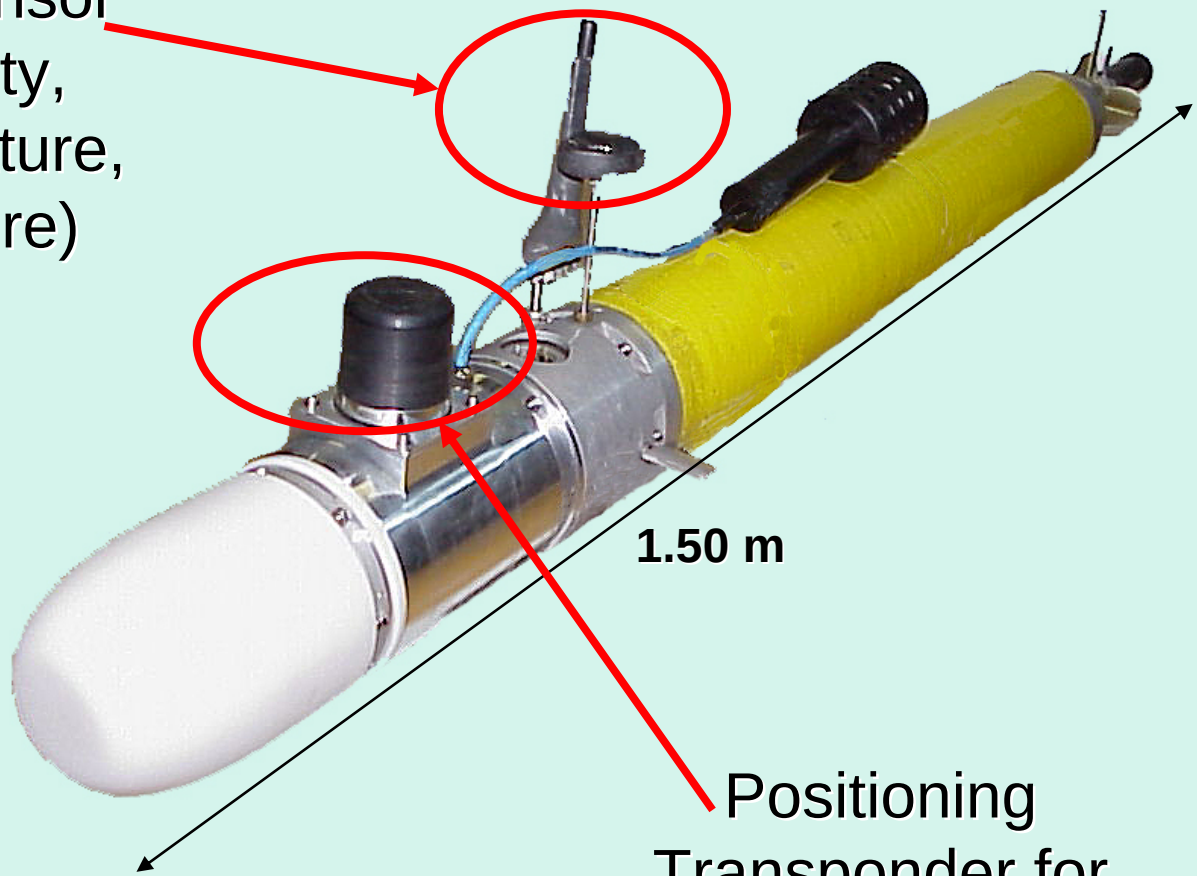
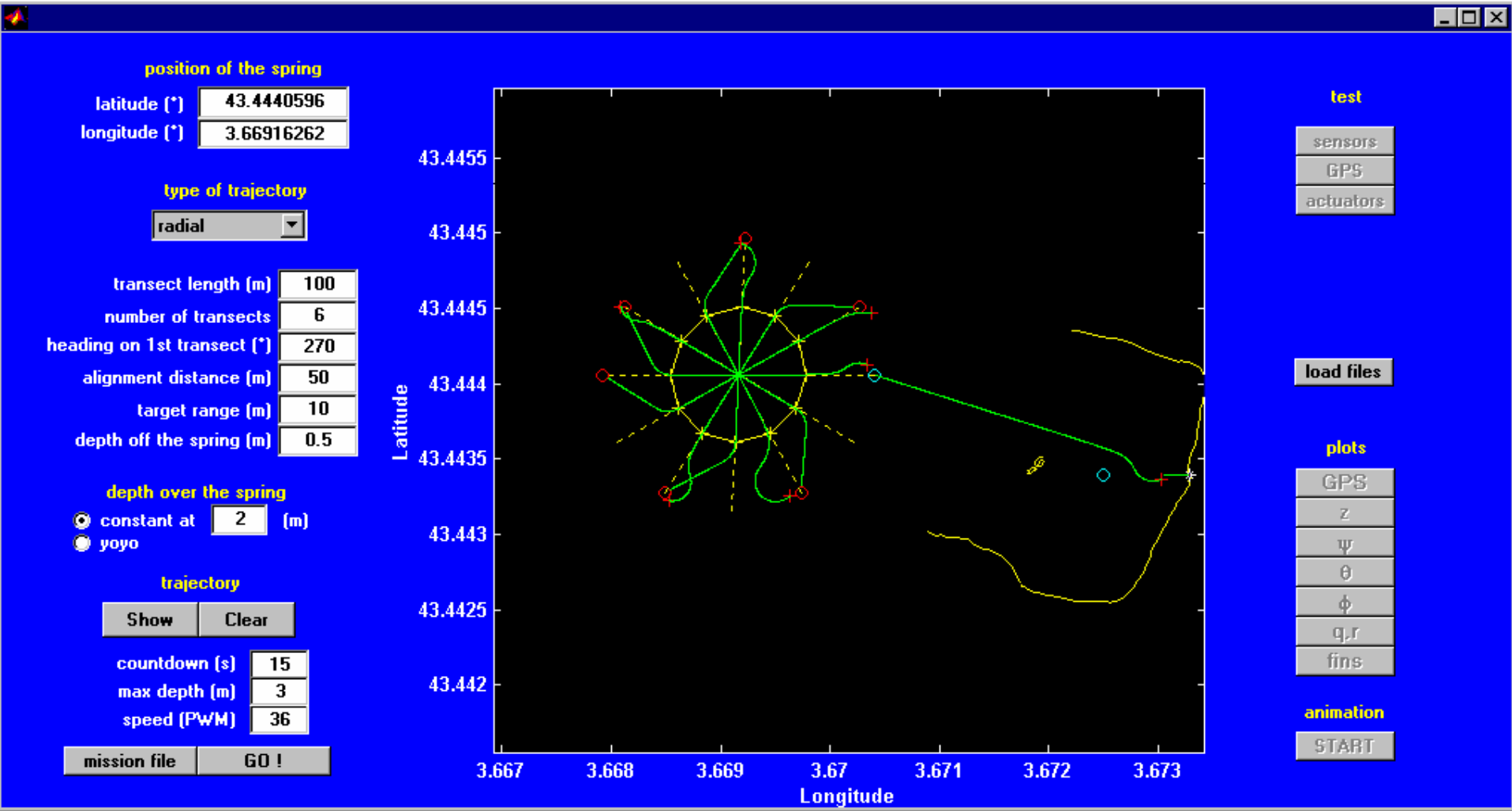


TAIPAN One



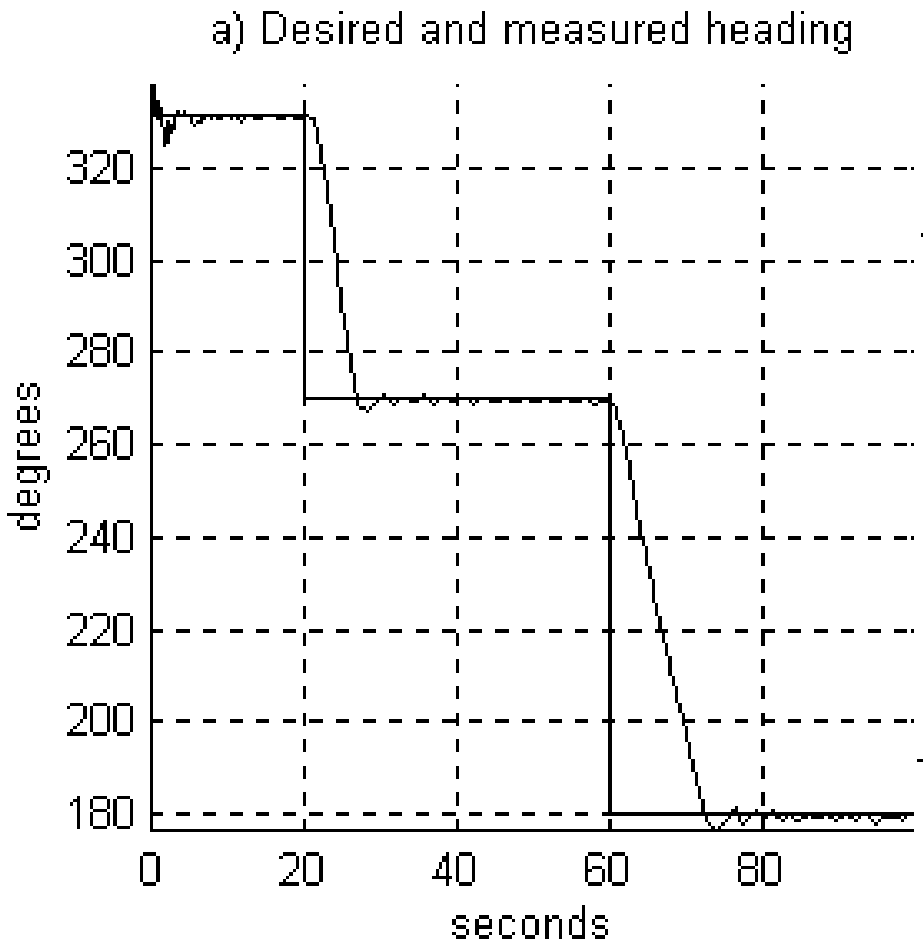
AXE 2

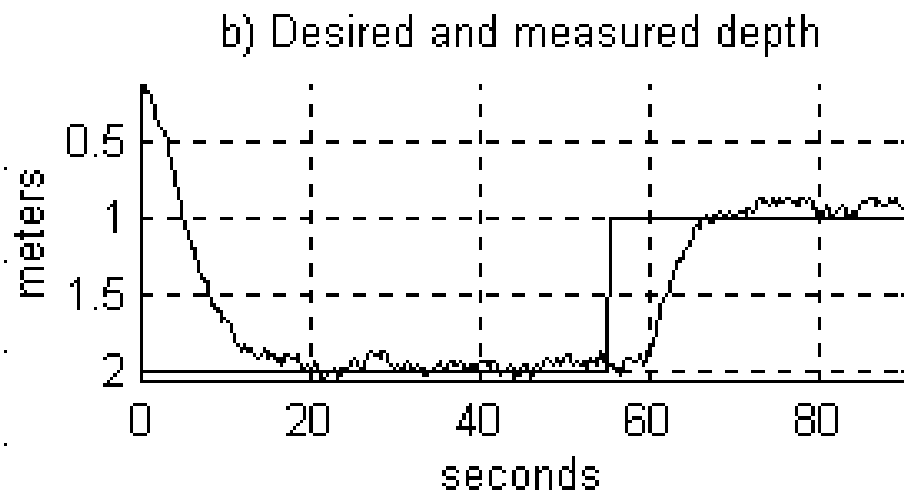
Mission Interface

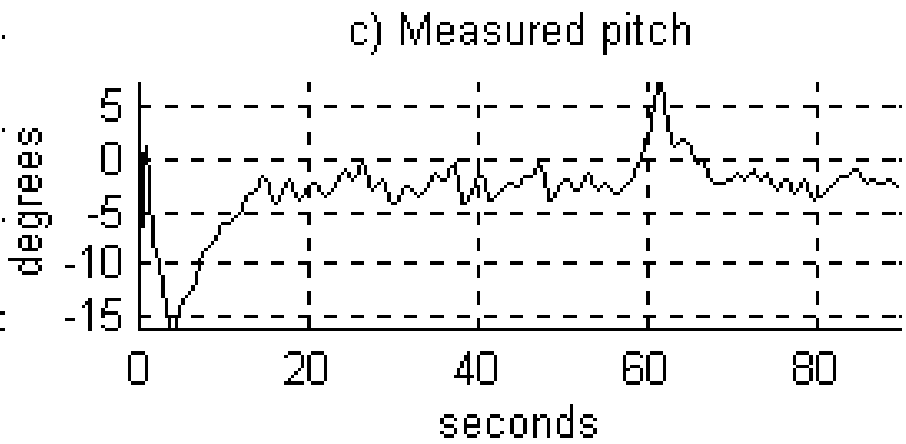


AXE 2

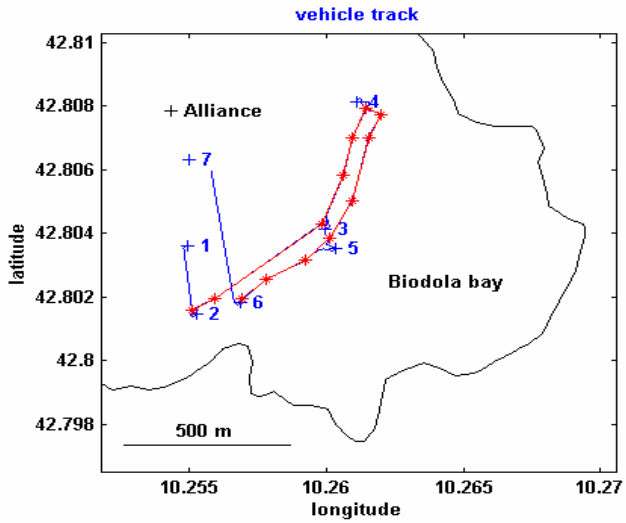
Vehicle Control

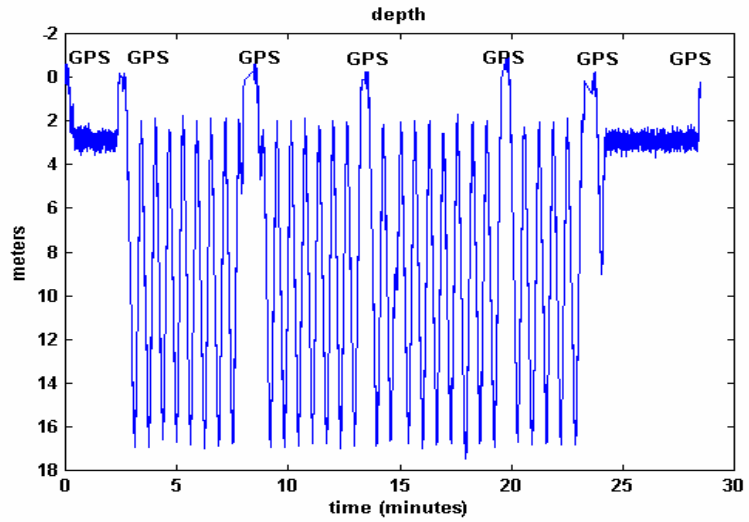


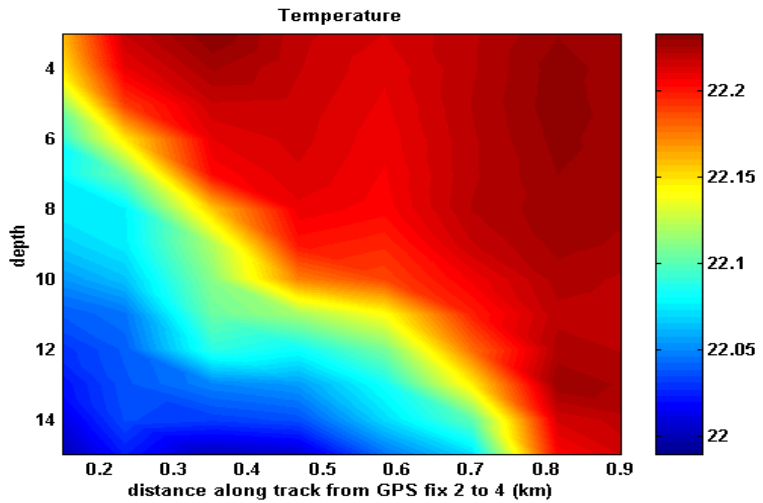


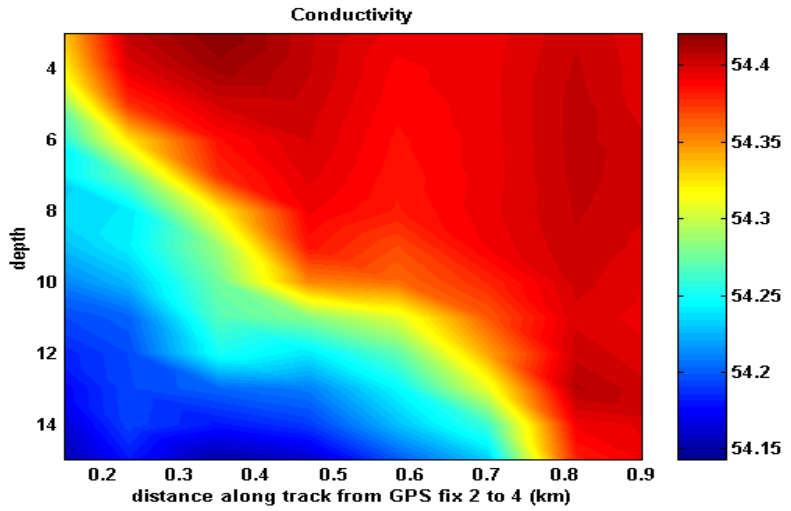


CTD Mapping with Taipan



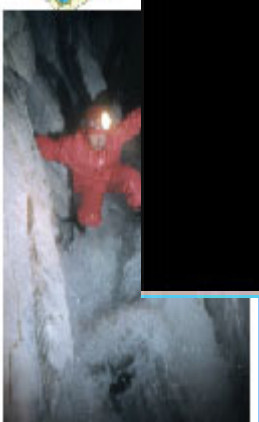




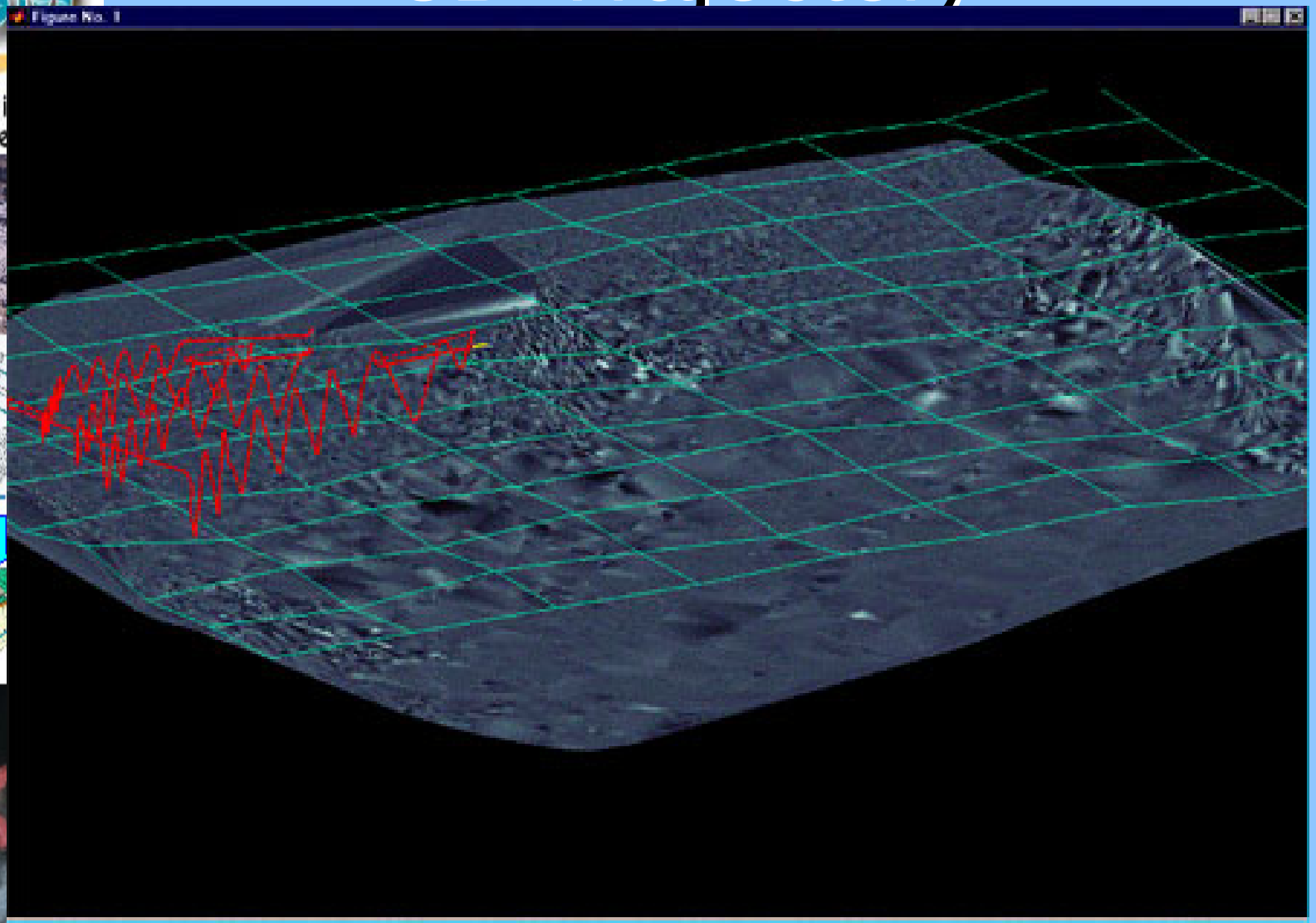


AXE 2

HydroSci
Montpe



3D Trajectory



AXE 2

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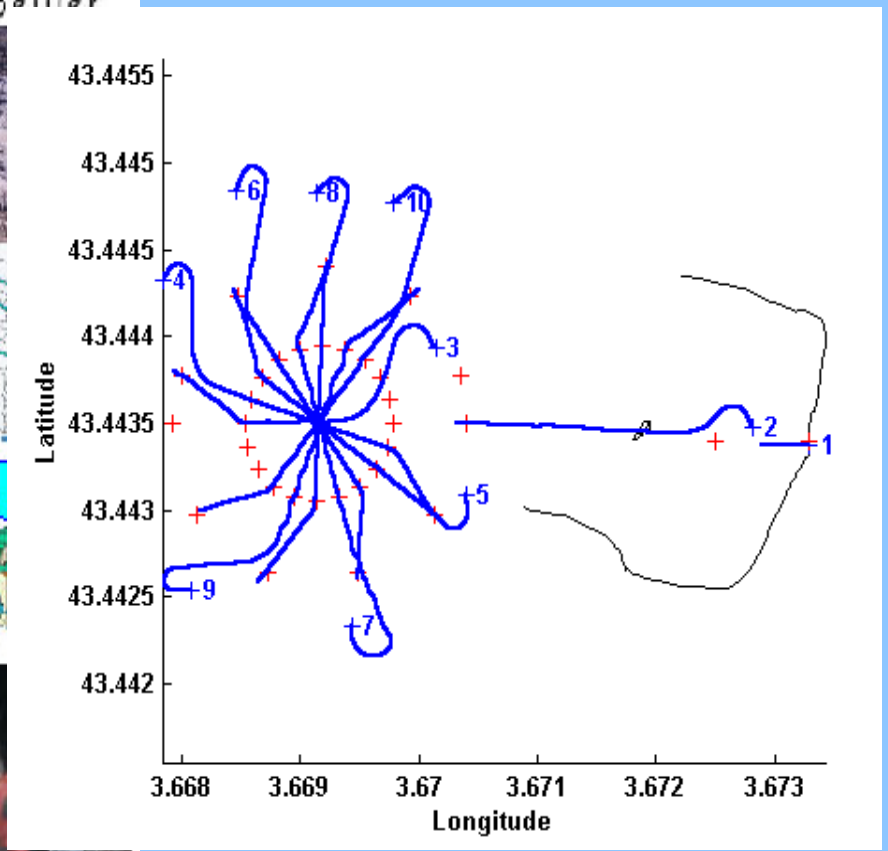
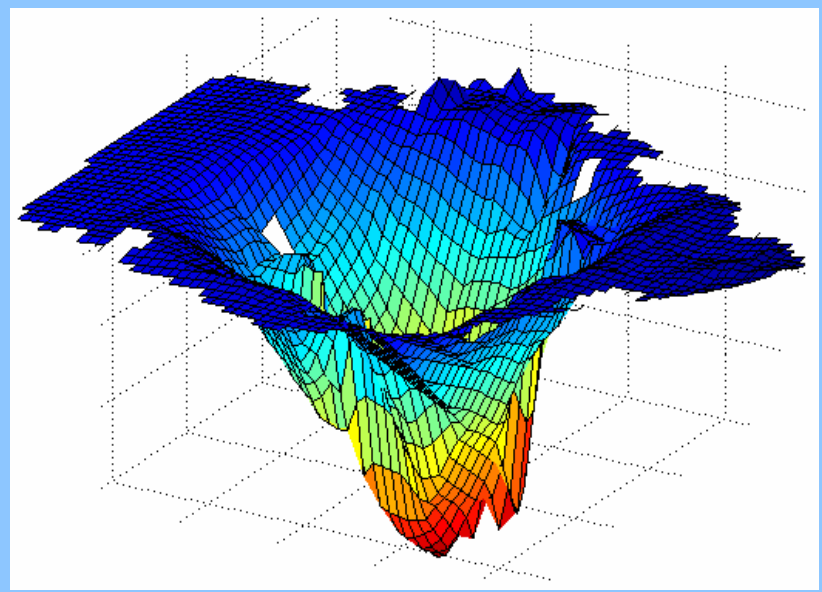
Thau Lagoon : the Vise KSMS



Real trajectories



Bathymetric measurements

AXE 2

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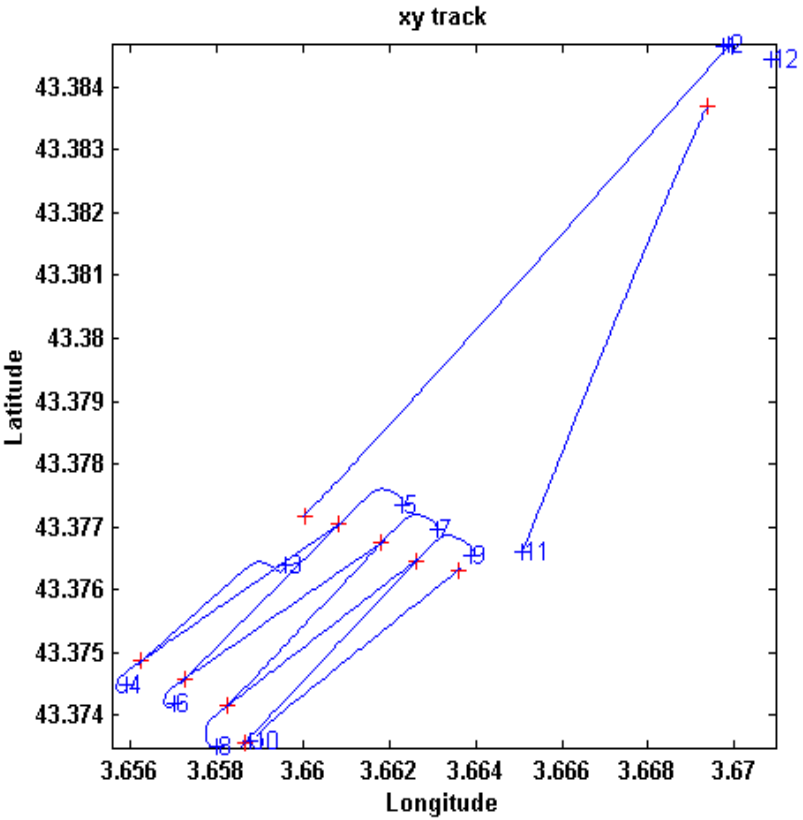
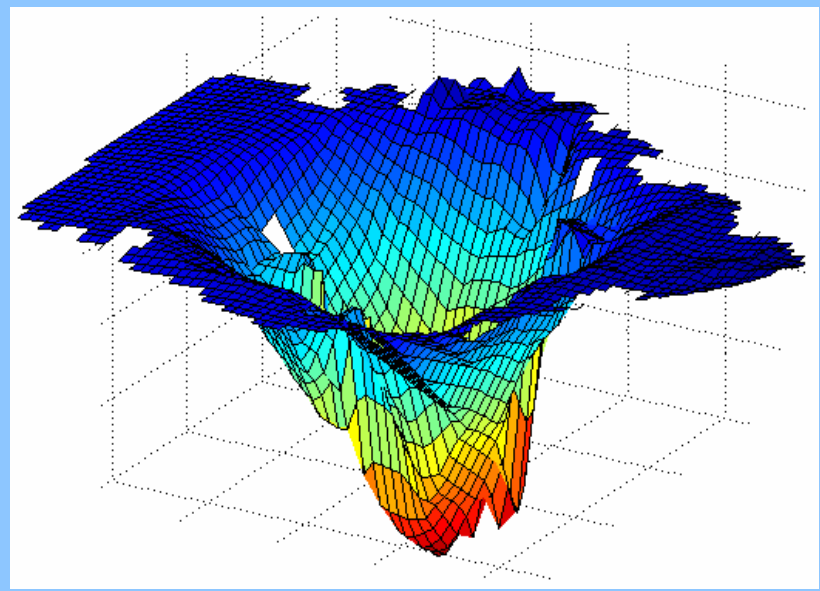
Thau Lagoon : the Vise KSMS



Real trajectories



Bathymetric measurements

AXE 2

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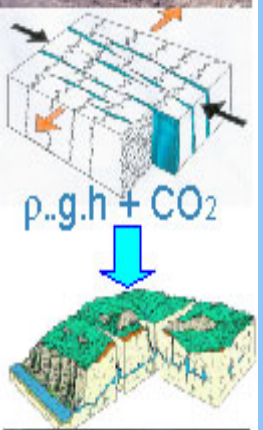

Topsolid view of the new AUV Taipan 2

UHF antenna

GPS antenna

Wifi antenna

CTD sensor

60 kg

1.80 m

Side Scan Sonar

ADCP

Acoustical sensor

0.20 m

AXE 2

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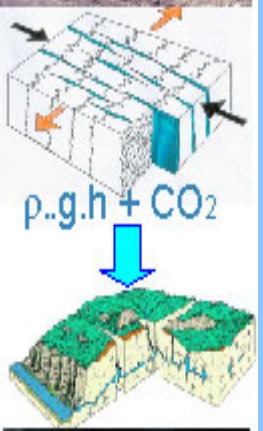

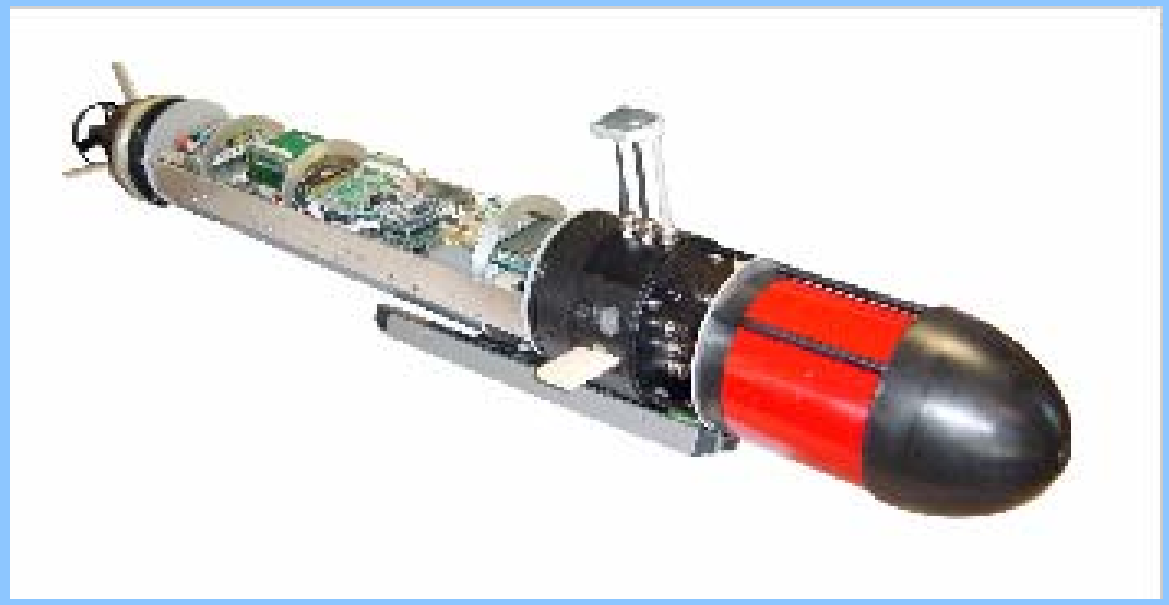

- Two onboard computers : navigation -- perception
- Additional card dedicated to :

  A/D conversions, RS232 serial communications, logical I/Os and PWM signal generation

AXE 2

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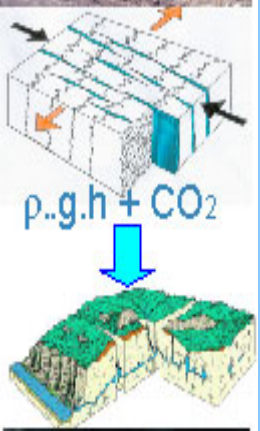

- **To compute displacement**
- three-axis inclinometer,
- three-axis magnetometer,
- yaw rate and pitch rate gyrometers and accelerometers
- two pressure sensors,
- loch doppler

- **For dead reckoning**
- Acoustical range meter
- GPS receiver

- **For communication**
- UHF radio link
- Wifi link

AXE 2

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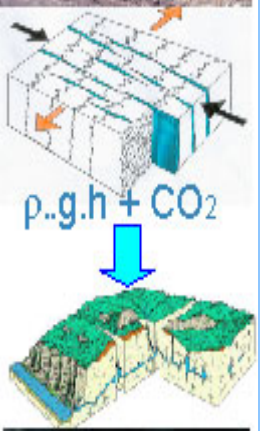

Scientific sensor payload

- CTD sensor
- Acoustical Doppler Current Profiler
- Side Scan Sonar
- CCD Camera
- Acoustical sensors (obstacle avoidance)

AXE 2

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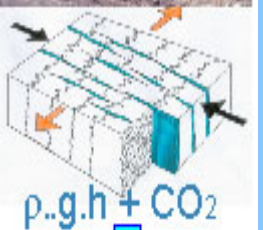
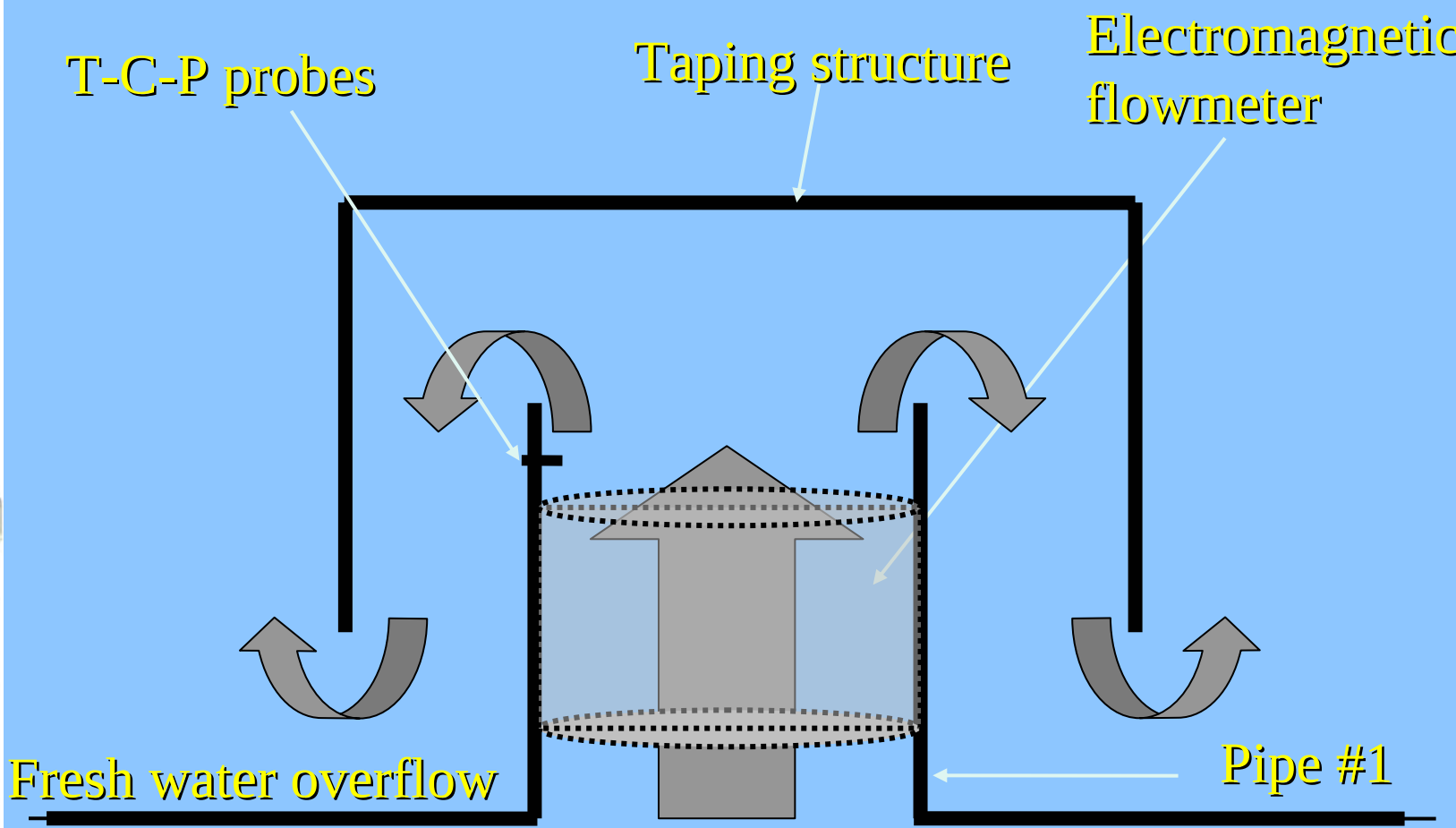


The KSMS instrumentation



AXE 2

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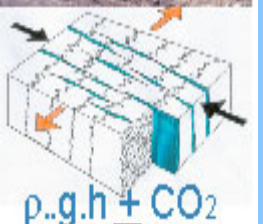

Principles of a taping system

1. Isolation of the KSMS from seawater and piping of fresh water
2. Fresh water flow should be driven by the density difference in the pipe

AXE 2

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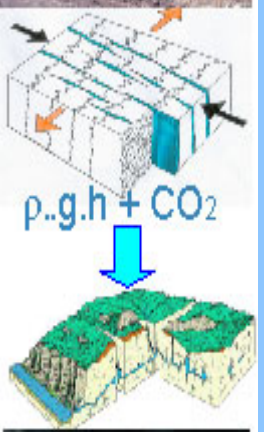

Principles of a taping system

cont'

3. The taping system should be open to the seawater to avoid too important changes of the hydraulic head during floods
4. The interface due to different density between fresh and sea water will push down seawater

AXE 2

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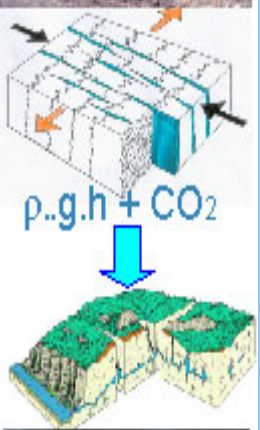

- MEDITATE offers the opportunity of assessing the groundwater resource from some karst submarine springs,
  - by measuring the instant flow rate in different hydrological conditions
  - by monitoring the time variations of flow and salinity of one of them as a reference

AXE 2

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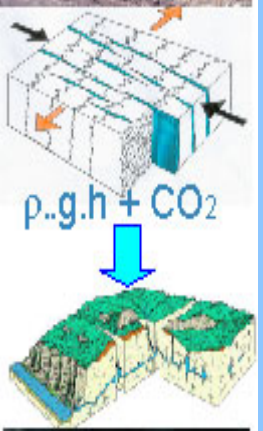

- Then, thanks to MEDITATE, we will know if some KSMS are an interesting groundwater resource to be exploited either by a direct off-shore tapping or by a on-shore exploitation from boreholes

AXE 2

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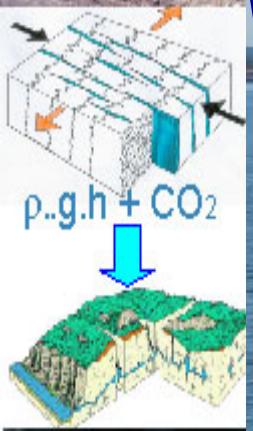

The end