European Airborne LiDAR Bathymetry Survey Campaign

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Rome, Italy

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Recap – ALB (Airborne LiDAR Bathymetry)

- Hydrographic Survey / Shallow Water Mapping sensor

- System mounted inside an aircraft

- Pulses of laser light (532nm wavelength) are used to measure the depth of water and height of features (ie rocks, islands, beach gradients)

- Technology designed originally for Nautical Charting applications. ALB technology is also used in other applications such as:

    - Coastal Zone Management including storm surge, flood and tsunami modelling
    - Repeat surveys for change monitoring
    - Marine and Coastal Engineering
    - Pre-Seismic surveys for O&G Industry
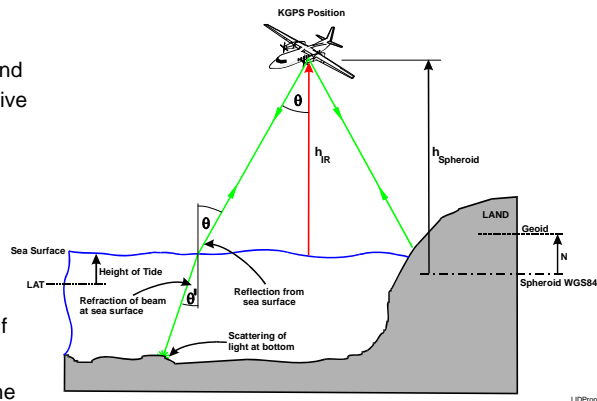   - Delineation of Baselines for EEZ/UNCLOS
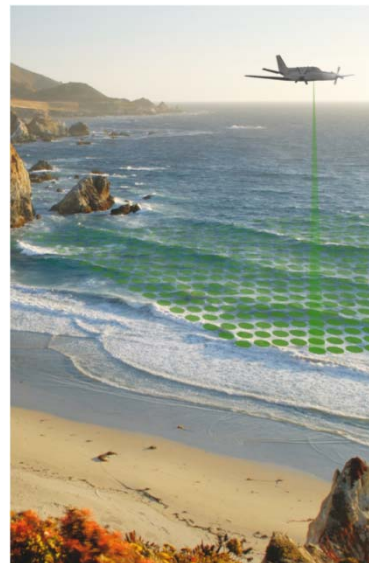
Brief explanation - how ALB works

- Laser pulse transmitted from aircraft at accurate known scan angle,
- Position and height of aircraft and platform accurately known relative to spheroid via post processed GPS / inertial measurements
- Height of aircraft above water surface known accurately by measurement of vertical laser pulse (IR or green)
- Tide independently measured, if required
- Depth is calculated from the time of flight between received laser pulses, speed of light, geometry …

KGPS Position

θ

h_{IR}

$h_{Spheroid}$

θ

LAND

Geoid

Sea Surface

Height of Tide

N

LAT

θ

Reflection from sea surface

Spheroid WGS84

Refraction of beam at sea surface

Scattering of light at bottom

LIDPronc.cd

Advantages of ALB

The shallow coastal zone is particularly difficult to survey. The benefits of ALB are:

- Seamless data across the land - water interface captured in the same epoch – very important as the coastal zone is dynamic, particularly in sedimentary areas
- Very productive, particularly in shallow water
- Completeness in complex areas
- Cost effective
- Rapid survey
- Safety in hazardous areas
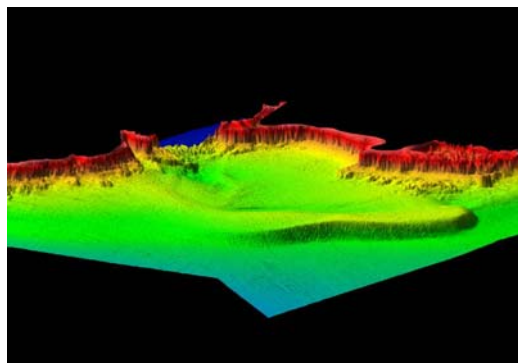
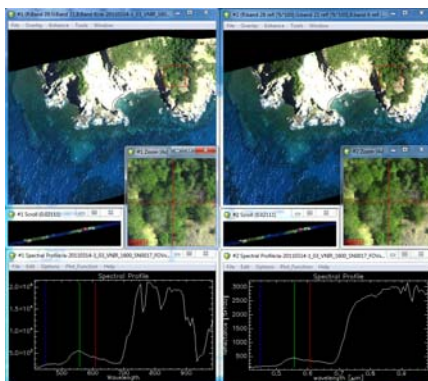## Additional sensors / products - digital imagery

- Digital imagery captured at 1Hz during survey
- Images linked to data processing software
- Images used during data processing / validation (QC) to review measurements.
- Images are georeferenced
- Data is overlayed / shown on image
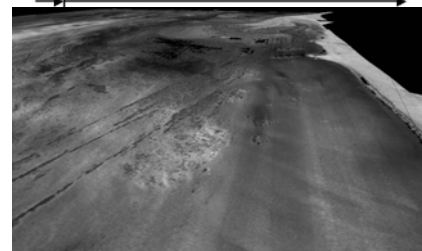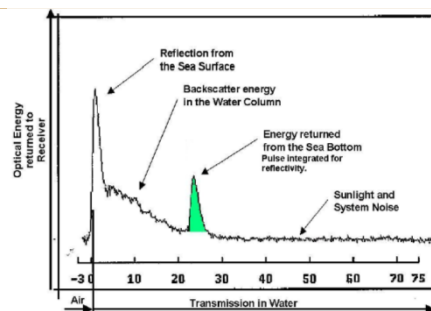- Can be mosaiced for larger image of survey area
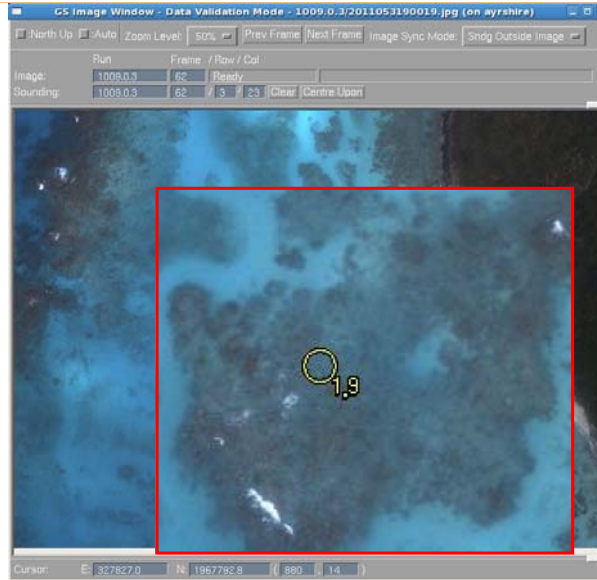
Additional sensors / products - hyperspectral and relative reflectance

NEO VNIR 1600 hyperspectral sensor
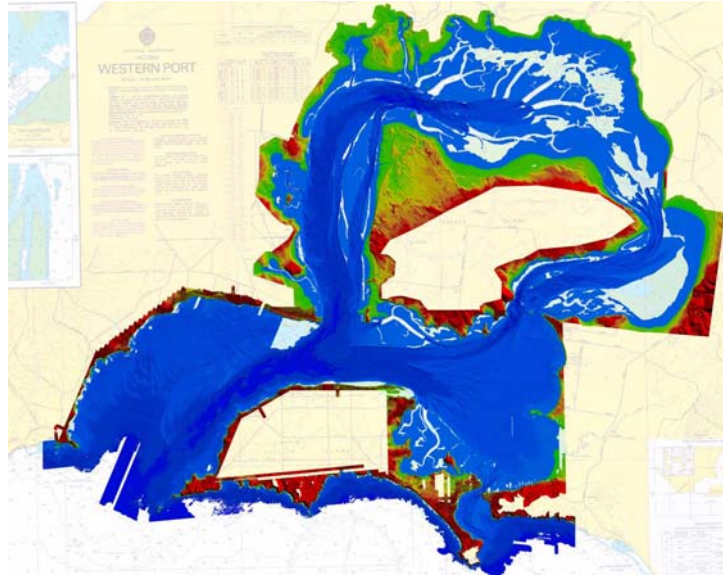
Relative reflectivity from raw laser waveforms

Additional sensors / products – ALB, topographic lidar and MBES

Westernport
Victoria –
combination of
ALB, topographic
lidar and MBES
(Multibeam Echo
Sounder) survey

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2012 ALB surveys in Europe

- In February 2012 Fugro commenced a large Airborne LiDAR Bathymetry (ALB) survey operation in Europe.
- Survey areas include large parts of the coastline in France: Finistere on the Atlantic coast and Provence, Alpes and Cotes d' Azur in the Mediterranean
- The survey areas cover in excess of 2,000 square kilometres of complex rocky coastlines, beaches, islands and reefs.
- Current status today: 76 flights conducted; data collection currently > 65% completed
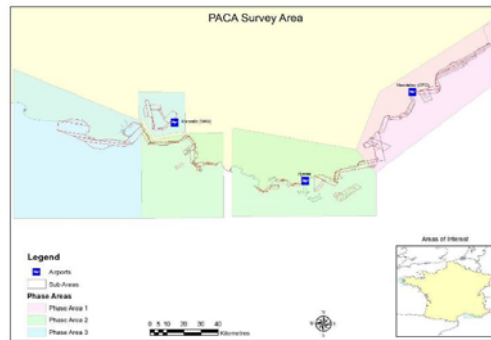
Principal Stakeholders and Areas
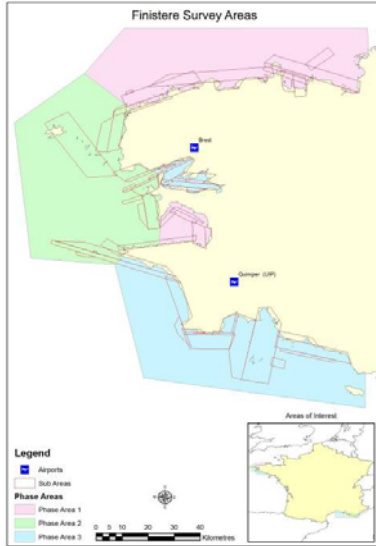
General Council of Finistère Planning Branch, Water, Environment and Housing, Department of Water Land Use Policies, QUIMPER

Regional Council Provence Alpes Cotes d'Azur (PACA) MARSEILLE

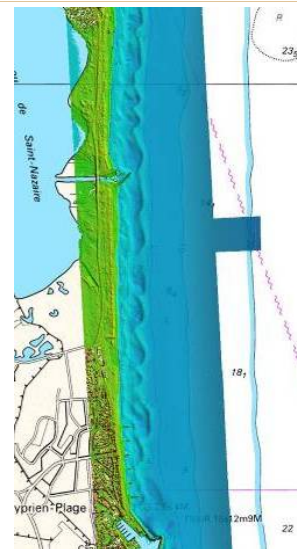**Service Hydrographique et Océanographique de la Marine (SHOM)** BREST

2012 ALB surveys in France

- Survey is for regional and national agencies for a number of applications for which a precise understanding of the coastal bathymetry is required.
- Products to support:
  - benthic habitat mapping for biodiversity
  - risk prevention including tsunami modelling
  - flood inundation mapping
  - coastline management including erosion and sand nourishment
  - economic development for ports
  - tourism and scientific research

2012 ALB surveys in France

- The survey requirements include the collection of data from the back of the beach to maximum depths of 20 to 30 metres to IHO Order 1b standards.
- A minimum coverage of the seabed of 80% in the Atlantic and 90% in the Mediterranean is required.
- Optical seabed reflectivity is a requirement in some areas to support seabed classification.
- The survey will be conducted using both a deep water ALB system and a shallow water ALB / topographic Lidar system set to work in a European registered aircraft.

2012 ALB surveys in France

- Survey was commenced in winter to avoid a particular problem on the seabed of the Atlantic coast of thick kelp

- State of the field of kelp in February

Image copyright @ AAMP - PNMI

2012 ALB surveys in France

Images copyright @ AAMP - PNMI

Winter storms strand massive kelp stranded on beaches

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Finistere survey area - kelp growth

Image copyright @ AAMP - PNMI

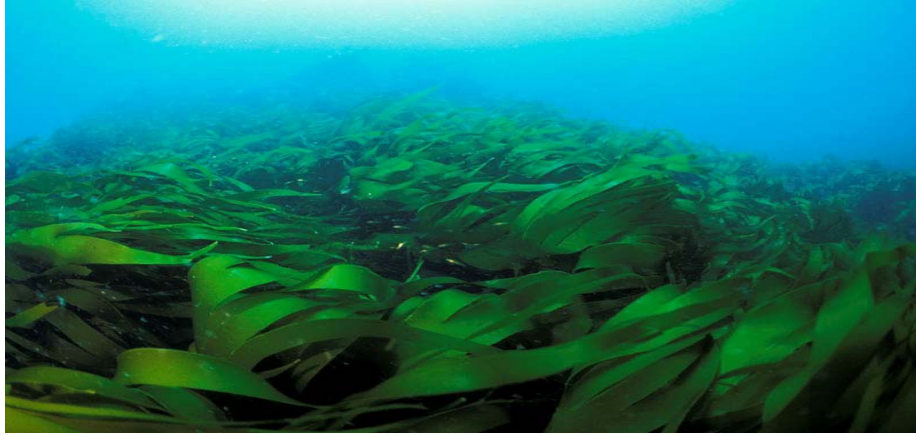Belts of himanthallia (distribution between 0 and 3 m) in summer

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Finistere survey area - kelp growth

Image copyright @ AAMP - PNMI

Belts of laminaria digitata (distribution between 0 and 5 m) in summer

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Finistere survey area - kelp growth

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Belts of laminaria hyperborea (distribution between 10 and 30 m) in summer

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Finistere survey area - kelp growth

Image copyright @ AAMP - PNMI

Seabed vegetation strata in summer

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Finistere survey area - kelp growth

Image copyright @ AAMP - PNMI

Impact – kelp may prevent seabed coverage if surveyed too late in the season

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2012 ALB surveys in France

Certain areas in Finistere need to be surveyed in winter / spring prior to kelp growth, however the weather is not always suitable

Certain areas of PACA are impacted by commercial activities in May, June and summer months.

Alternative areas are assigned and planned for each flight in the event that conditions are not suitable in the primary area

ALB surveys have the benefit of the operational flexibility of an aircraft to freely move within and between survey areas to avoid unsuitable environmental conditions

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Contractors

- **Fugro Geoid (Montpellier, France)** provide contract management, local logistics support and in-field quality control and management of the high density topographic data
- **Fugro LADS (Adelaide, South Australia)** provide the ALB planning, data collection and processing services and integration of the data to produce the products for delivery to SHOM.
- *RIEGL* **Laser Measurement Systems GmbH (Horn, Austria)** provide and set to work of the new VQ-820-G hydrographic Airborne Laser Scanner alongside the LADS Mk 3 system in the CASA 212.
- **BLOM CGR (Parma, Italy and St-Didier au Mont d'Or France)** provide the CASA 212 survey aircraft, set to work and trials of the LiDAR equipment in the aircraft in January in Italy, aircraft operations and management of the flight authorizations in France.

Prior projects: compare and contrast …

- A similar survey was conducted in 2008 / 2009 for Victorian Government Department of Sustainability and Environment (VicDSE) for the Future Coasts program – reported at **FIG 2010 - Sydney**
- The purpose of that project was to prepare Victoria's coast for climate change.
- The effects of rising sea levels due to thermal expansion, glacial and ice sheet melt and increased storm surges due to changing weather patterns can lead to inundation and erosion or accretion. In addition, tsunamis can lead to catastrophic destruction.
- These events present risks to environmental, social and economic assets.
- The aims of this program are to identify the types of threats and adaption strategies for the Victorian coastline and inform planning, decision making and strategy development.
- This project involved:
  – operations from multiple ALB and terrestrial lidar sensors
  – sea level observations from a large number of tide gauges deployed along the coastline to accurately model the mean sea level
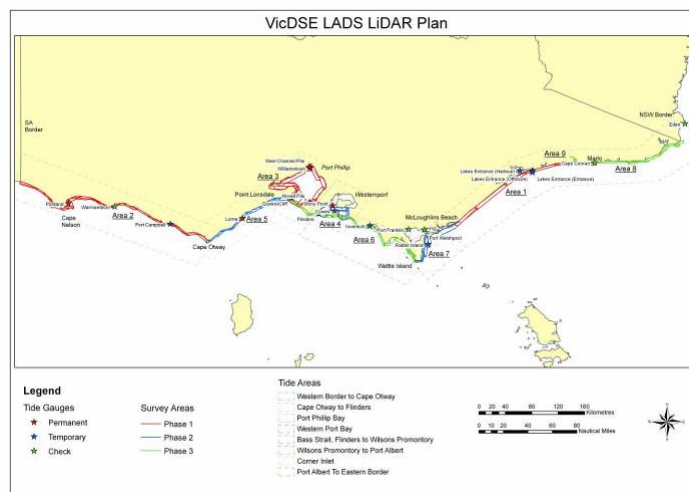 – A network of new and existing GPS reference stations
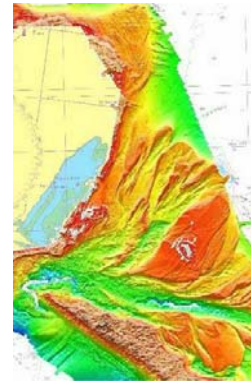
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Fugro LADS LiDAR Plan

- The plan divided the coast into 9 areas in three project data collection phases to maximise flexibility and reduce downtime due to weather
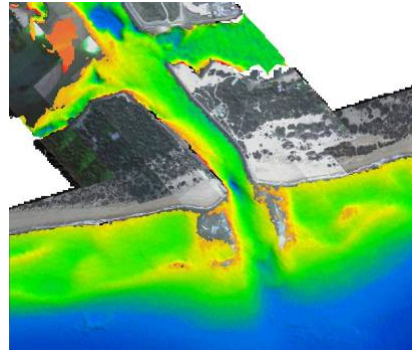

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Fugro LADS LiDAR Plan

Approach

- Three complementary LiDAR systems and MBES were used
- In general, areas were allocated to each sensor as follows:
  - ALB surveyed the coastline
  - Topographic lidar used to survey turbid areas of Westernport at low water when exposed
  - MBES used in highly turbid areas in Westernport
- All Field work to be undertaken during 2008 / 2009 summer.
- Processing of LiDAR data and DEM generation to take place throughout 2009

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New system development

- The Victoria survey was predominantly conducted using the LADS Mk 2 system fitted into a DHC-8 aircraft
- Since that time, a new LADS Mk 3 system has been developed (reported at **FIG 2011** Marrakesh)
- The new system is smaller and lighter and more efficient to operate whilst maintaining or improving upon the robust performance features of its predecessor systems. It is designed for operation in a wider range of aircraft, such as Cessna 441, Cessna 208, Casa 212 …

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Fugro LADS Mk 3

- **Key System Enhancements**
  1. Reduced size and weight – installable in aircraft of opportunity
  2. Faster laser, the system was launched initially with a 1.5 KHz laser with room for expansion, without loss of laser power (currently testing 2kHz upgrade)
  3. Improved physical and optical design of the transmit and receive sides of the system, through improvements to the optical coatings on mirrors, lenses and windows to improve the reflectivity and transmission.
  4. 7 degrees cross-track and roll compensation.
  5. The system has depth performance of 80 metres (clear water conditions).
  6. Extended operating heights from 1200 – 3000 feet, to provide very wide swath widths
 7. Wider swath widths up to 585m and variable resolutions

LADS Mk 3

High data quality

- LiDAR Bathymetry data is only as good as the quality of the raw laser waveforms. This is affected by the following:
  - water clarity
  - depth of water
  - time of day: ie: day (incl. sun angle) / night (removal of the green filter)
  - seabed reflectivity
  - laser power and receiver aperture and gain applied to the signal
  - operating height
- These attributes affect the quality of the recorded data. The best measure of quality is the signal to noise ratio (**SNR**) of the raw laser waveforms.
- It is extremely important to achieve soundings with a high **SNR**, to minimize the effects of noise, as high SNR waveforms facilitate:
  - discrimination of the seabed from noise
  - detection of the seabed to IHO Order 1 accuracy
  - detection of features/targets on the seabed
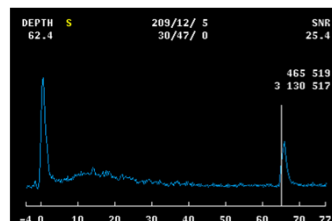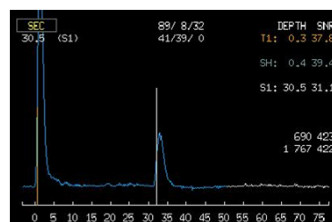
raw waveforms

Introducing a new capability – high density shallow water ALB and topographic data

- New Riegl VQ820G system has just been developed by Riegl
- For this survey, Riegl system has been integrated with LADS Mk 3 system in the same aircraft
- Both systems operate at 532nm
- LADS system scans under the aircraft, Riegl is angles 20 degrees aft
- Systems complement each other providing coverage on the coast and offshore to deep water (LADS) and very high density coverage in very shallow water and on the beach and coast (Riegl)

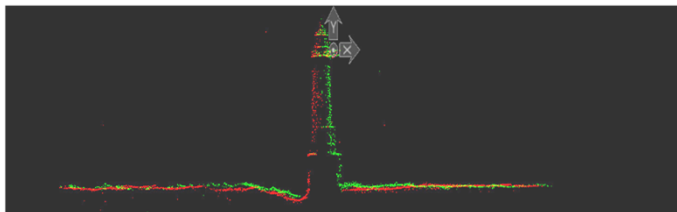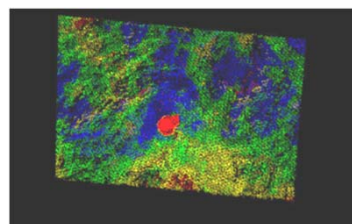

LADS Mk 3 and Riegl VQ820G mounted in CASA 212
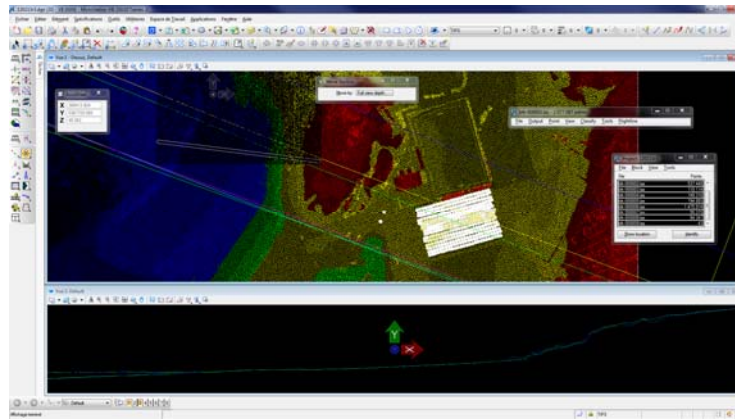
Riegl VQ820G system

- Operated in 138kHz mode
- ~ 1.5 point / sq m on the ground & in the water, at typical ALB survey speed / operating height
- Depth measurement up to 10 metres observed
- Laser footprint size ~ 0.6m at typical ALB operating height
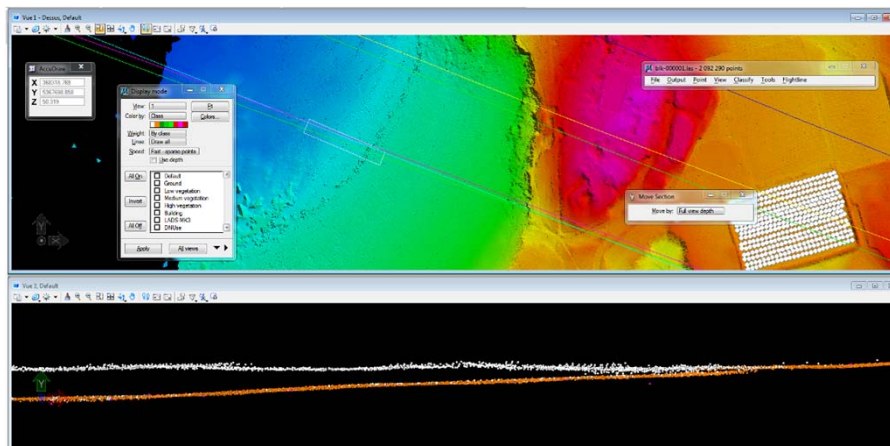- Operated at 42 degree fov, scan ~ 20 degrees aft

Riegl data

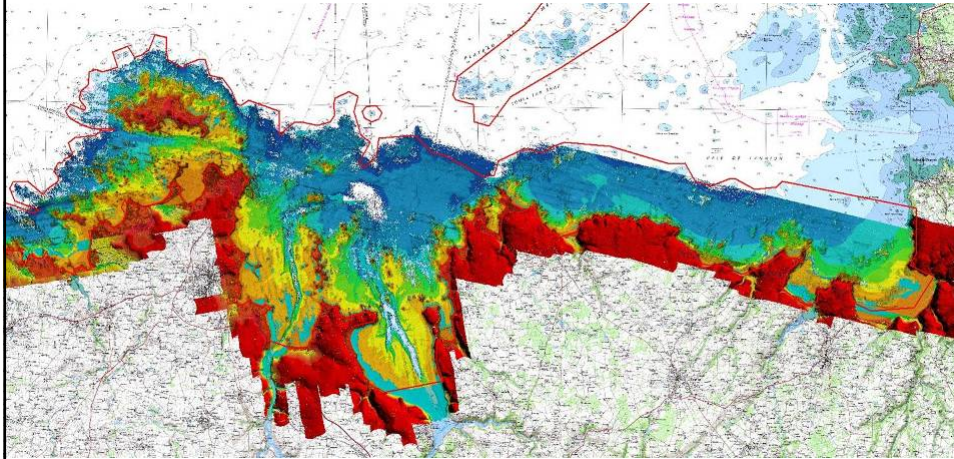Riegl VQ820G data over the coastline and offshore

Combined LADS and Riegl data sets

LADS Mk 3 and Riegl VQ820G data over the coastline and offshore

LADS and RIEGL Coverage – at 8 May 2012

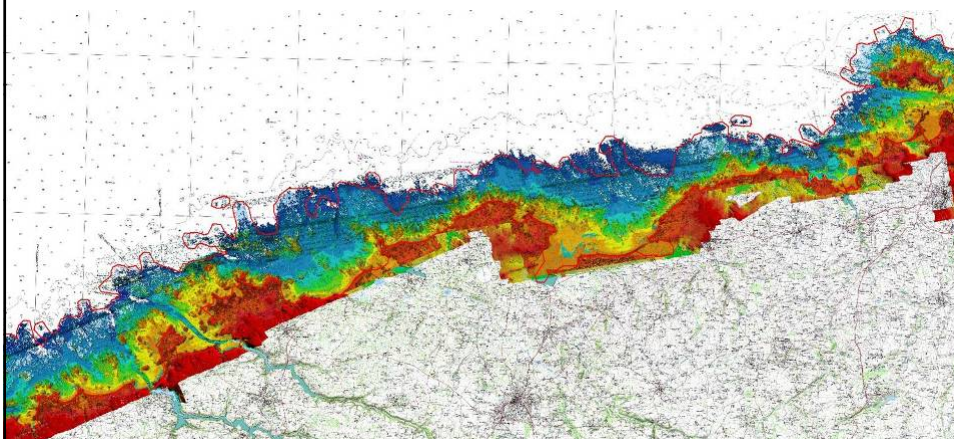Zone "North Finistère"

April 10, 2012   www.fugro.com

LADS and RIEGL Coverage – at 8 May 2012

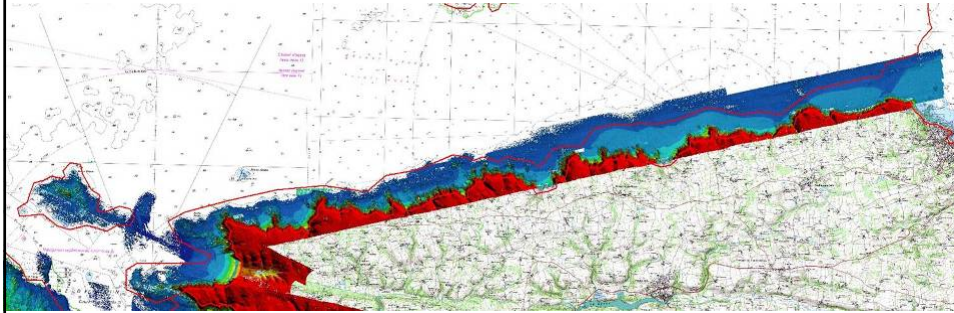Zone "North West Finistère"

April 10, 2012   www.fugro.com

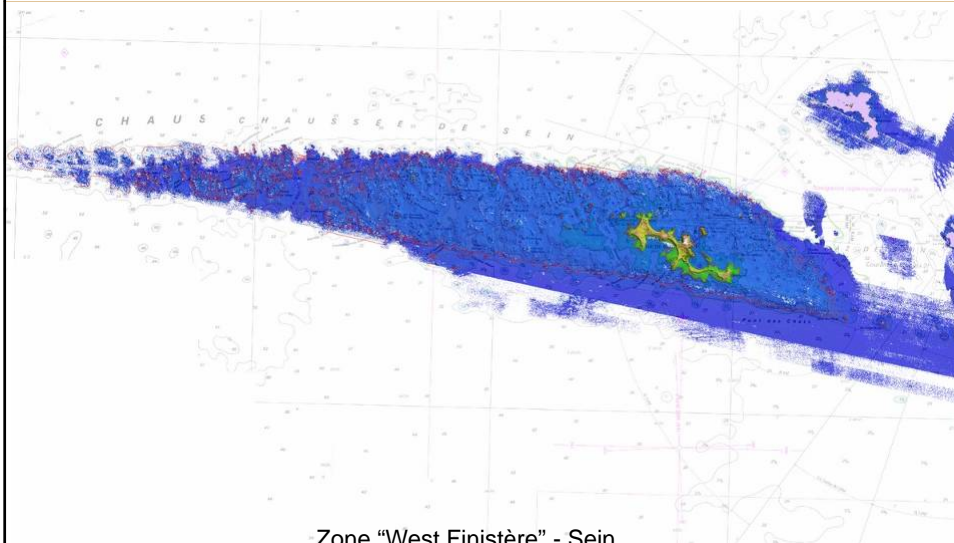**LADS and RIEGL Coverage – at 8 May 2012**

Zone "West Finistère"

April 10, 2012
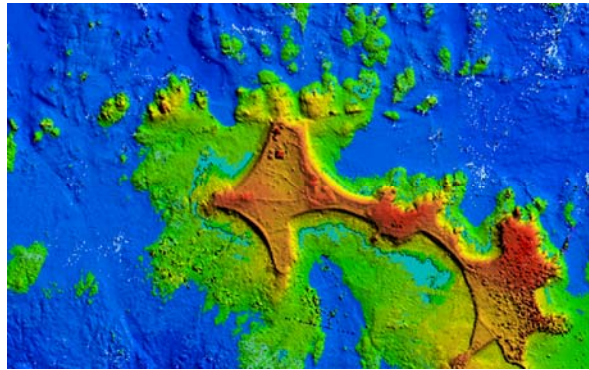
www.fugro.com

LADS and RIEGL Coverage – at 8 May 2012

Zone "West Finistère" - Sein

April 10, 2012

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LADS and RIEGL Coverage – at 10 April 2012

Part of "West Finistère" - Sein

Compare and contrast – 2012 surveys in France & 2008 / 2009 in Victoria

- Victoria: 3 aircraft used with 3 different topographic / bathymetric sensors
- France: LADS Mk 3 integrated with the new Riegl VQ820G system in single aircraft for simultaneous topographic and deep water coverage (LADS) and high density coverage inshore and topographic (Riegl)
- Victoria: multiple tide gauges deployed, surveyed relative to sea surface and reduced to MSL datum
- France: surveying on ellipsoid – GPS used for height control and no deployment of tide gauges
- Victoria: use of multiple GPS base stations along the coast for position control
- France: use of PPP (Precise Point Positioning) GPS for position and height – no deployment of GPS base stations
- Predominantly one operating site in Victoria (Essendon), two in France, in Finistere (Brest) and PACA (Hyeres)
- Common approach: large surveys conducted in phases, to manage environmental constraints

Thank You

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