NCSR
National Centre for Sensor Research

Insight

Integrating Geospatial Remote and in-Situ Sensing: Opportunities and Challenges

Margaret McCaul, Jack Barland, Eoghan McNamara, Sean Jordan, John Cleary, Conor Calahane*, Tim McCarthy* and Dermot Diamond

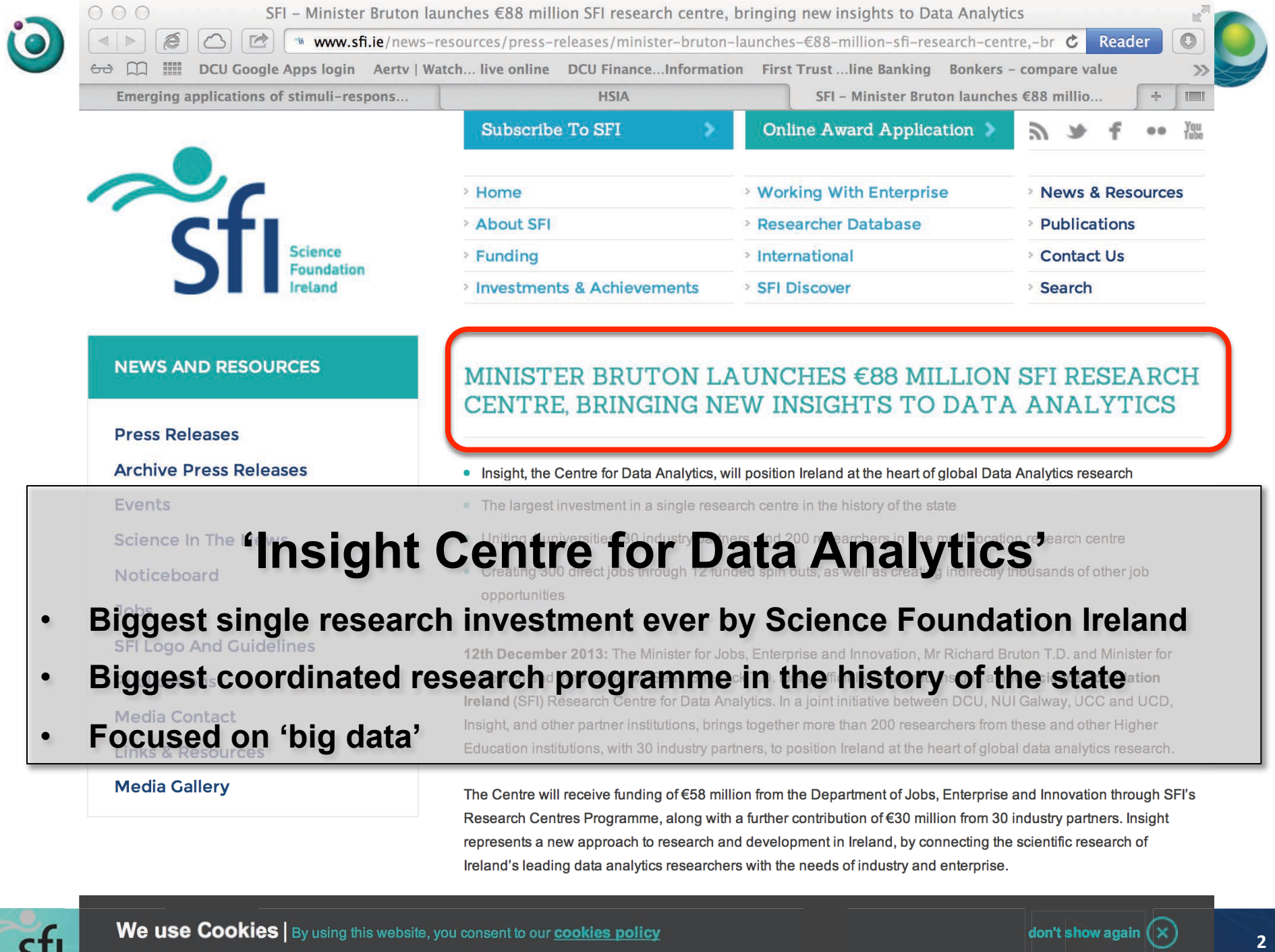
INSIGHT Centre for Data Analytics, National Centre for Sensor Research, Dublin City University
****National Centre for GeoComputation, NUI Maynooth***

Invited Keynote Lecture presented at

ISEH 2016, ISEG 2016 & Geoinformatics 2016

NUI-Galway, 17th August 2016

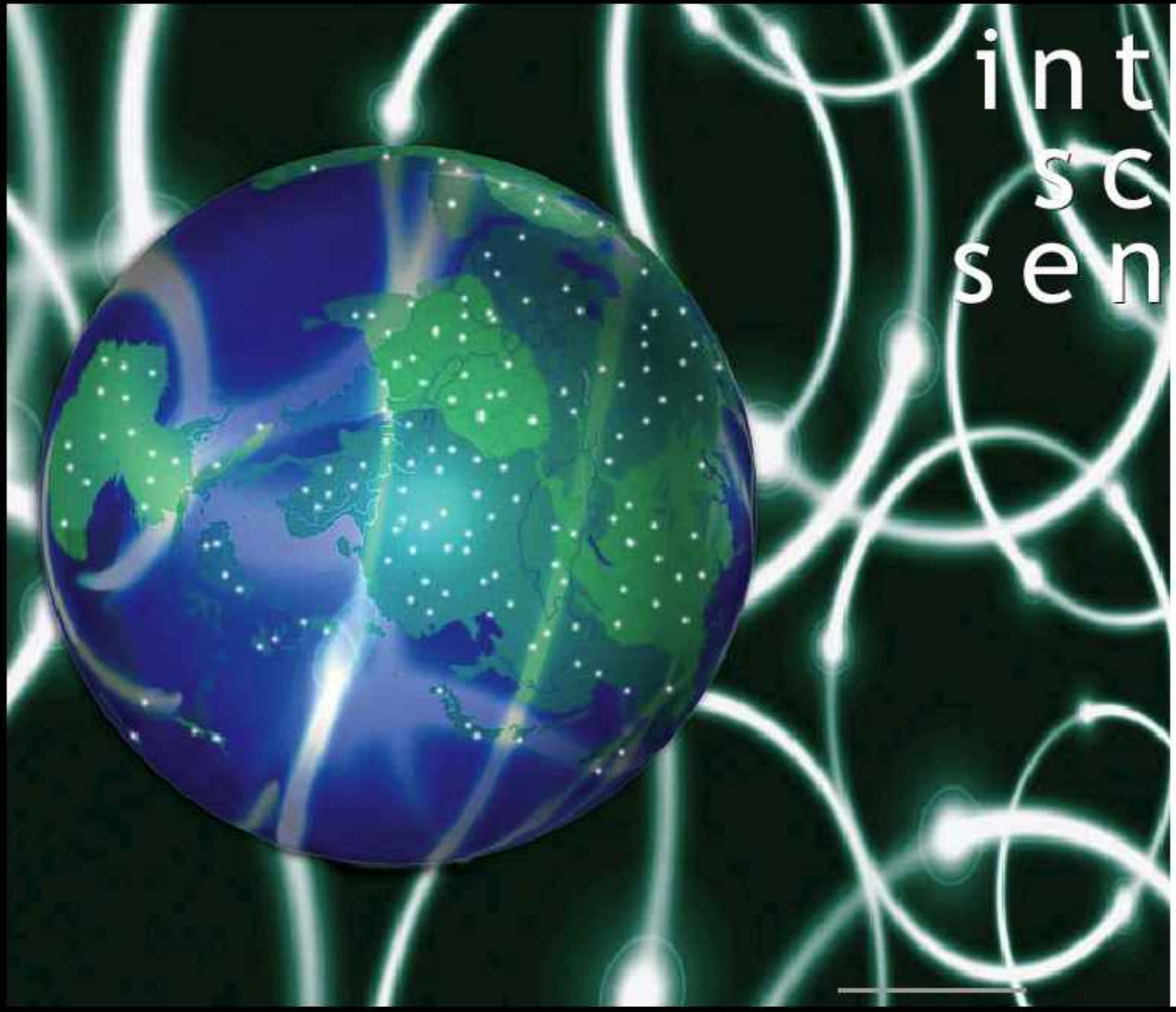
sfi DCU UCC OÉ Gaillimh NUI Galway UCD DUBLIN



'Insight Centre for Data Analytics'

- **Biggest single research investment ever by Science Foundation Ireland**
- **Biggest coordinated research programme in the history of the state**
- **Focused on 'big data'**

Keynote Article: August 2004, Analytical Chemistry (ACS)



internet scale sensing

Dermot Diamond
Dublin City University
(Ireland)

Incredible advances in digital communications and computer power have profoundly changed our lives. One chemist shares his vision of the role of analytical science in the next communications revolution.

Digital communications networks are at the heart of modern society. The digitization of communications, the development of the Internet, and the availability of relatively inexpensive but powerful mobile computing technologies have established a global communications network capable of linking billions of people, places, and objects. Email can instantly transmit complex documents to multiple remote locations, and websites provide a platform for instantaneous notification, dissemination, and exchange of information globally. This technology is now pervasive, and those in research and business have multiple interactions with this digital world every day. However, this technology might simply be the foundation for the next wave of development that will provide a seamless interface between the real and digital worlds.

The crucial missing part in this scenario is the gateway through which these worlds will communicate: How can the digital world sense and respond to changes in the real world? Analytical scientists—particularly those working on chemical sensors, biosensors, and compact, autonomous instruments—are

Dermot Diamond, Anal. Chem., 76 (2004) 278A-286A
(Ron Ambrosio & Alex Morrow, IBM TJ Watson)

Remote (Continuous) Sensing Challenges: Platform and Deployment Hierarchies

Physical Transducers –low cost, reliable, low power demand, long life-time

Thermistors (temperature), movement, location, power,, light level, conductivity, flow, sound/audio, ……

Chemical Sensors – more complicated, need regular calibration, more costly to implement

Electrochemical, Optical, .. For metal ions, pH, organics…

Biosensors – the most challenging, very difficult to work with, die quickly, single shot (disposable) mode dominant use model

Due to the delicate nature of biomaterials enzymes, antibodies….

Increasing difficulty & cost

Increasing scalability

Gas/Air Sensing – easiest to realise

Reliable sensors available, relatively low cost

Integrate into platforms, develop IT infrastructure, GIS tools, Cloud Computing

On-land Water/ Monitoring

More accessible locations

Target concentrations tend to be higher

Infrastructure available

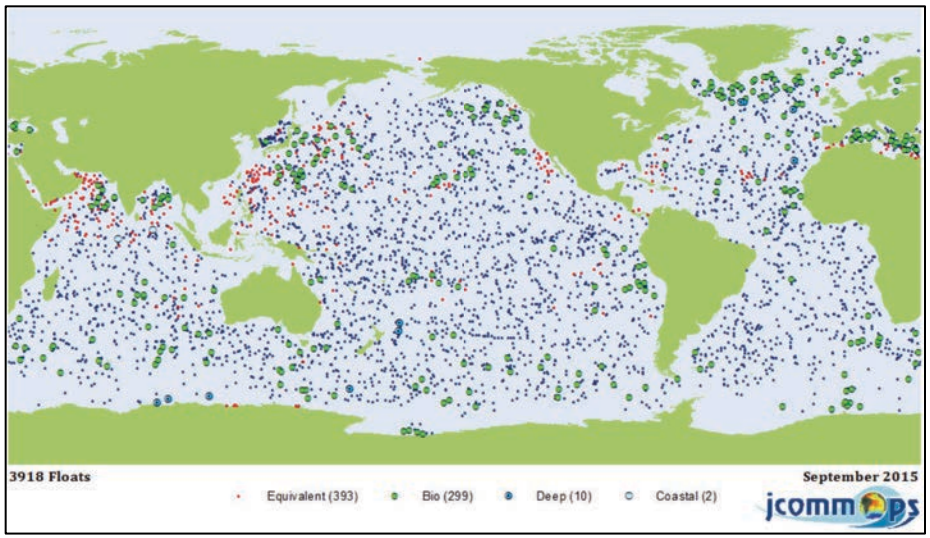
Marine Water

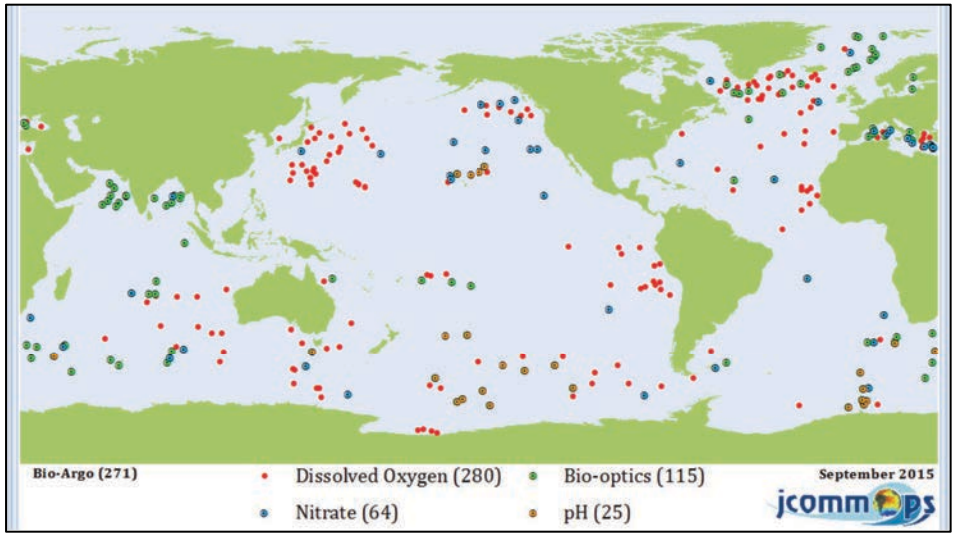
Challenging conditions

Remote locations & Limited infrastructure

Concentrations tend to be lower and tighter in range

Argo Project (accessed March 20 2016)





- Ca. 4,000 (3918) floats: temperature and salinity
- Bio/Chem: Nitrate (64), DO (280), Bio-optics (115), pH (25)

DO is by Clark Cell (Sea Bird Electronics) or Dynamic fluorescence quenching (Aanderaa)

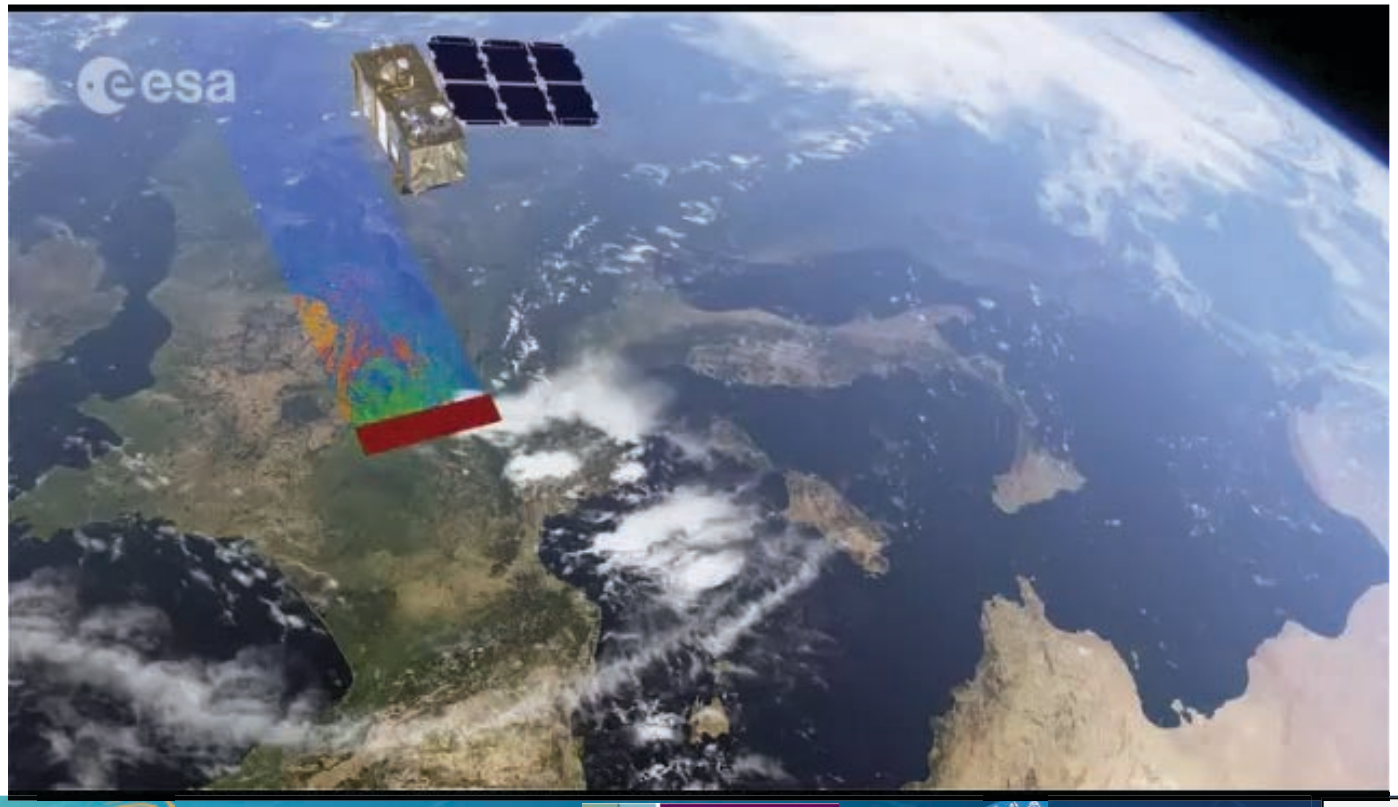
@€60K ea!

See https://picasaweb.google.com/JCOMMOPS/ArgoMaps?authuser=0&feat=embedwebsite

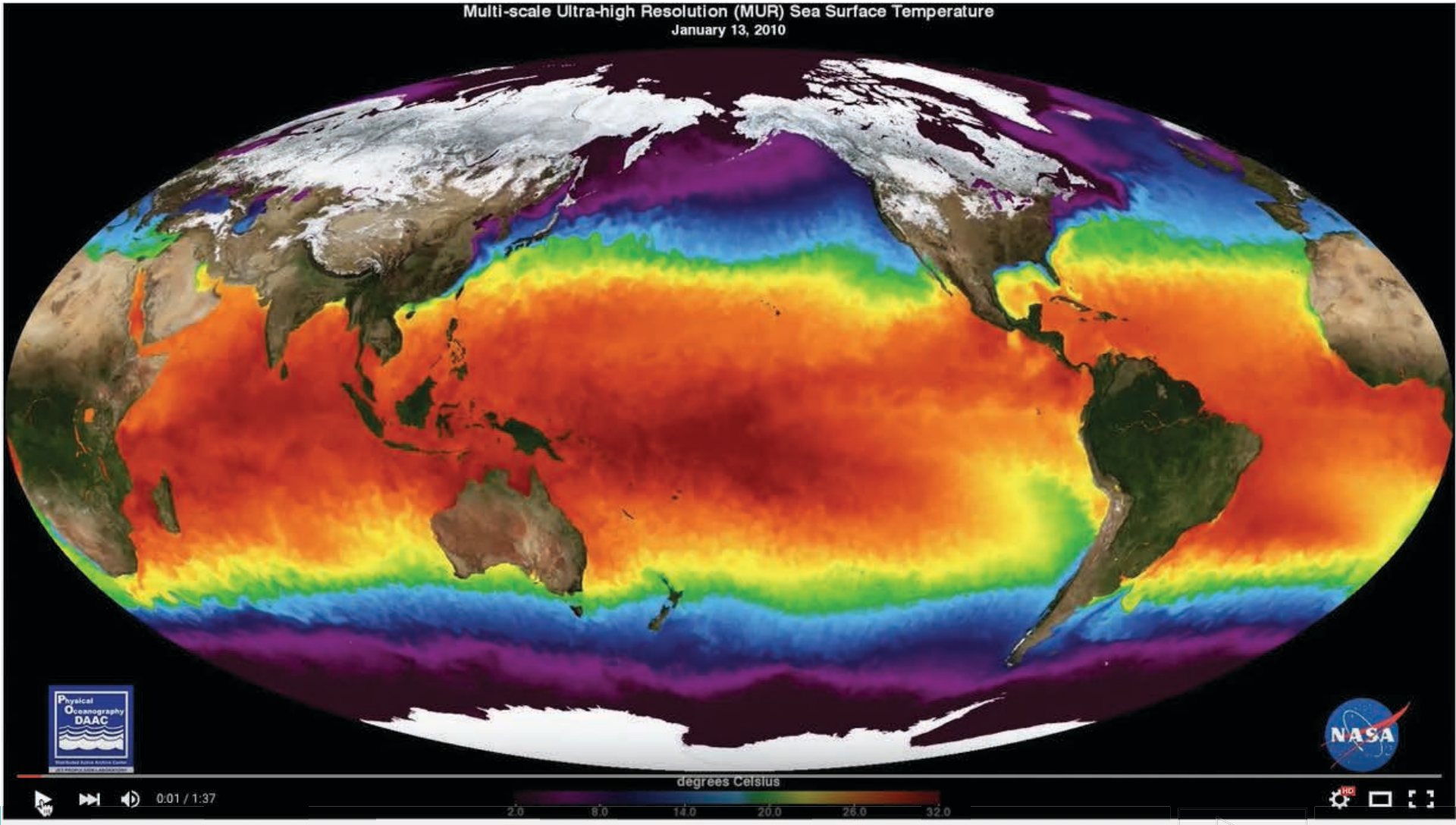
'calibration of the DO measurements by the SBE sensor remains an important issue for the future', Argo report 'Processing Argo OXYGEN data at the DAC level', September 6, 2009, V. Thierry, D. Gilbert, T. Kobayashi

Satellite Remote Sensing

- **Big Data:** An IKONOS **4-band multispectral image** at **1-m** pixel size covering an area of 10 km by 10 km, digitized at 11 bits (stored at 16 bits), has a data volume of **200 MB per image**.
- Coverage is not continuous
- Image quality depends on weather



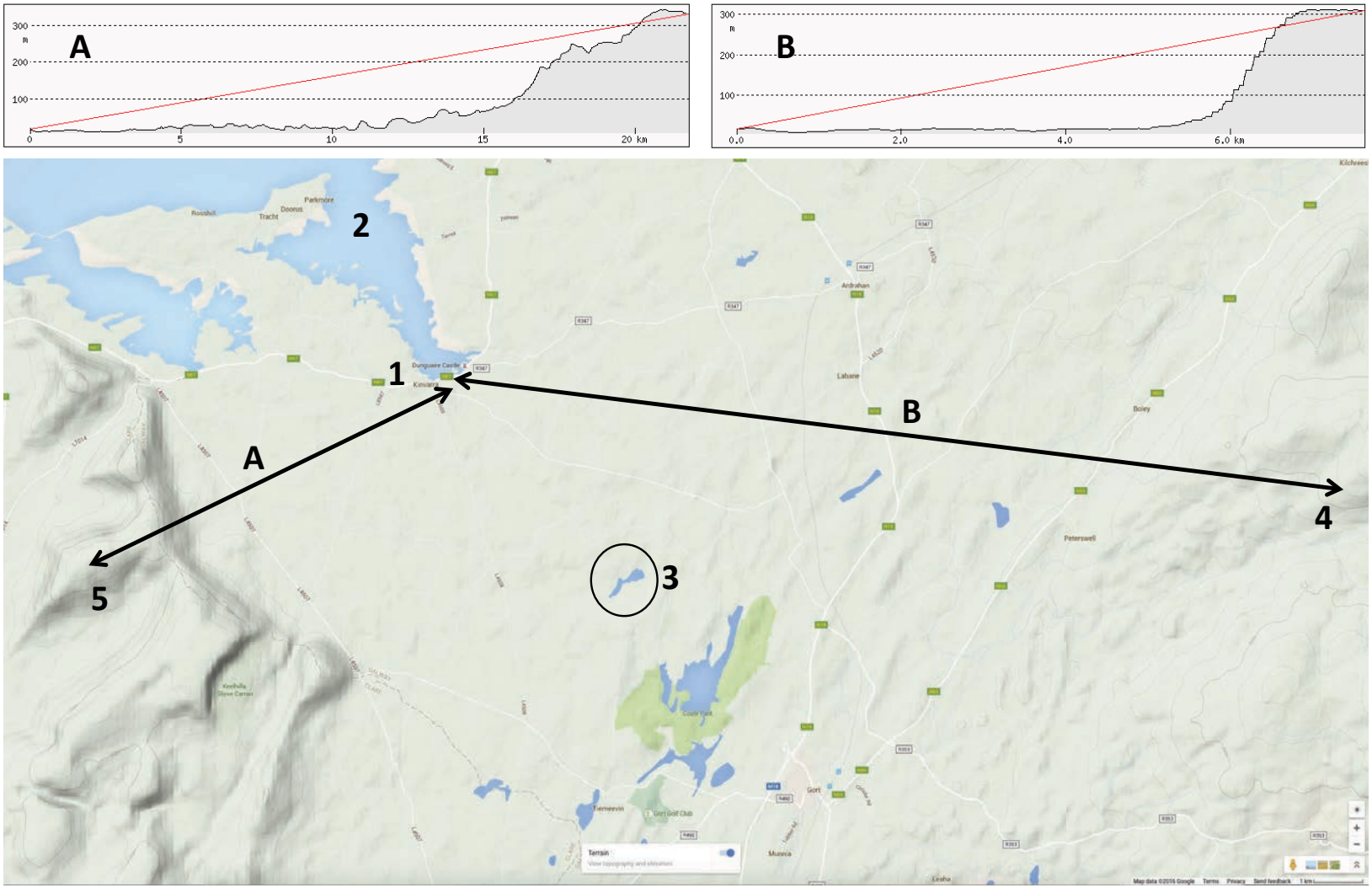
Global Sea Surface Temperature Patterns



The Multi-Scale Ultra-High Resolution (MUR) Sea Surface Temperature (SST) Data Set Animation

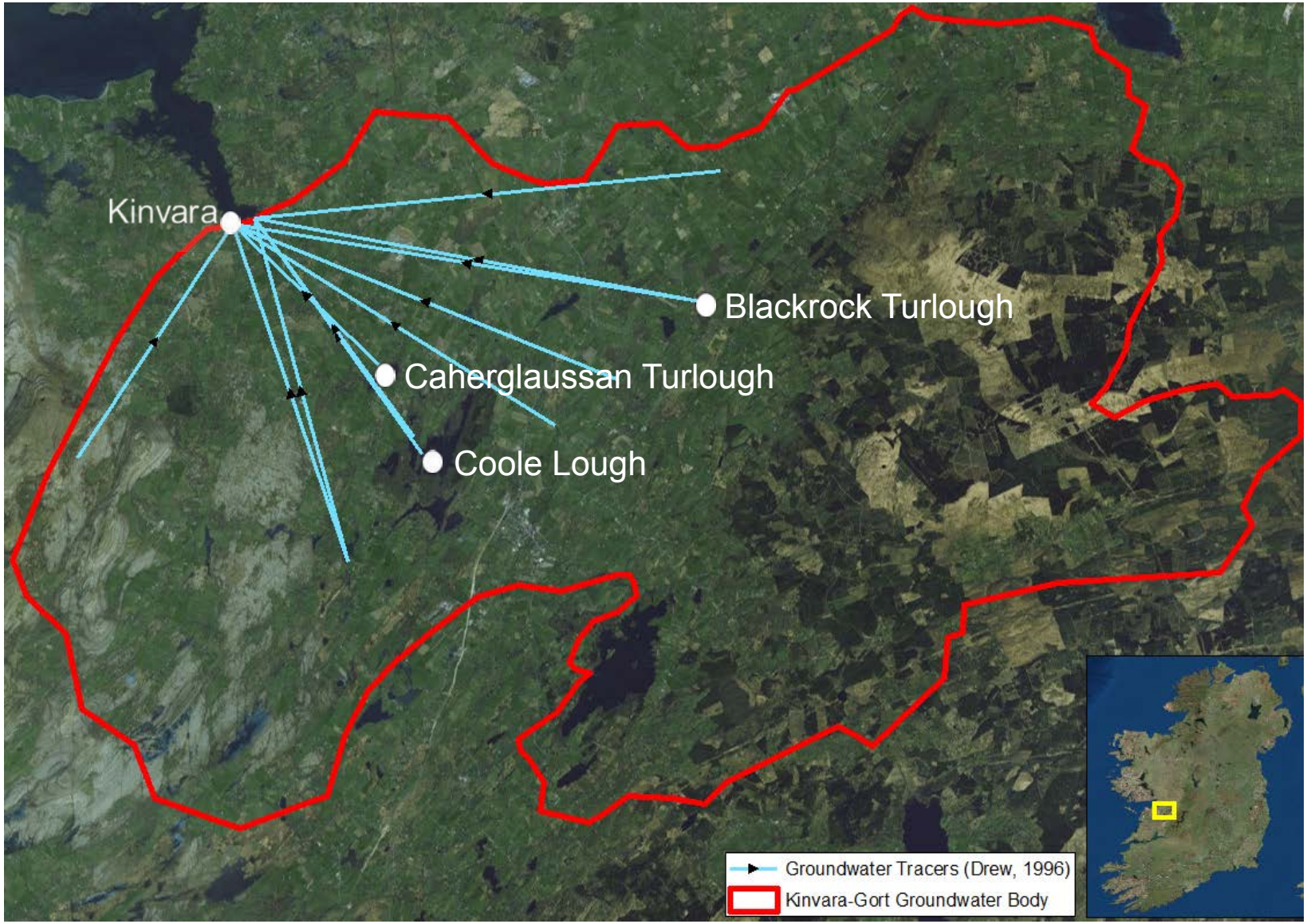

Inver
Screebe
Camus
Oughter
Salalee
Kilkieran
Bealadangan
Costelloe
Derroe
Rossaveel
Carraroe
Lettermullan
Trabane
Coral Strand
Inverin
Cathair
Spiddal
Furbogh
Barna
Moycullen Bogs
Cloghaun
Moycullen
Annaghdown
Lough Corrib
Corrandulla
Lackaghbeg
Loughgeorge
Claregalway
Galway Technology Park
Ballybane
Galway
Salthill
Oranmore
Tawin
Clarinbridge
Kilcolgan
Killeeneen
Craughwell
Aggard
Caherpeak
Ballinderreen
Rathcosgrove
Doorus
Flaggy Shore
Furbo
Kinvarra
Labane
Peterswell
Bealaclugga
Ballyvaughan
Murroogh
Formoyle
Fanore
North Atlantic Ocean
Shrawn
Mainistir
Kilronan
Gort Na gCapall
Inishmaan
An Tra
Deelin
Meggagh
Carran
Kilmoon
Lisdoonvarna
Doolin
Kilfenora
Leamaneh
Cloon
Killinaboy
Ballyportry
Moyree
Blakemount
Kilkeedy
Tubber
Boston
Shanaglish
Tierneevin
Gort
Leaha
Ballinruan
Corofin
Crusheen
Inchicronan
Rannagh
Ruan
Lahinch
Ennistimon
Liscannor
St bridget's Well
Athenry
Bengarra
Shraugh
Monivea
Tiquin
Briarhill
Derrydonnell
Kiltullagh
Carrarea
Cahercastle
Carrabane
Kilchreest
Flagmount
Caher
Aylevaun
Feakle
GALWAY
CLARE

Kinvara Region - Topography



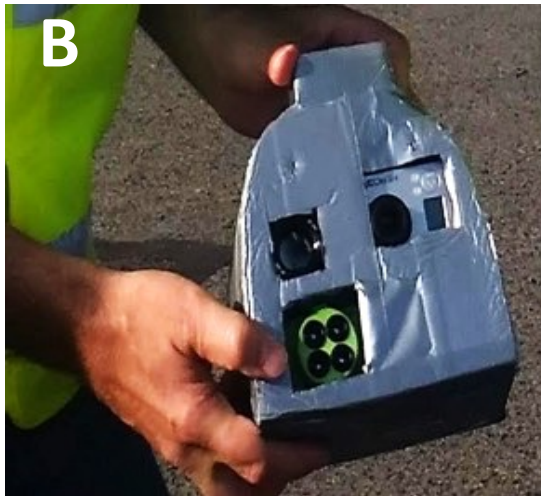
(1) Kinvara; (2) Kinvara Bay; (3) Caherglassuan Turlough; (1-4) Section A from Kinvara Eastwards towards Peterswell and the Slieve Aughty Region (4); 1-5 Section B from Kinvara Southwest towards Slieve Carran

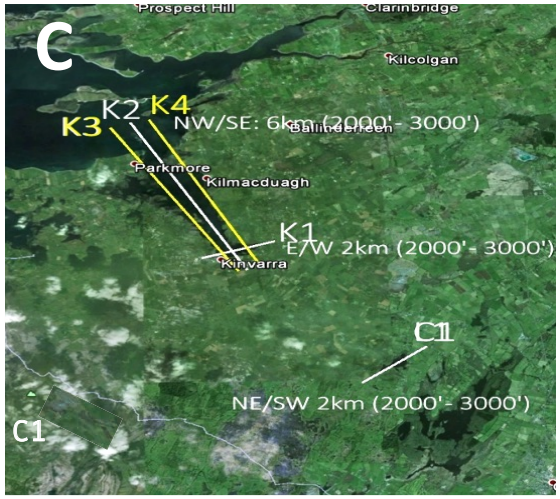
Kinvara: Hydraulic Connection



Sentinel-2 Hi-Res Satellite (August 27, 2015) resolution 10-20 m

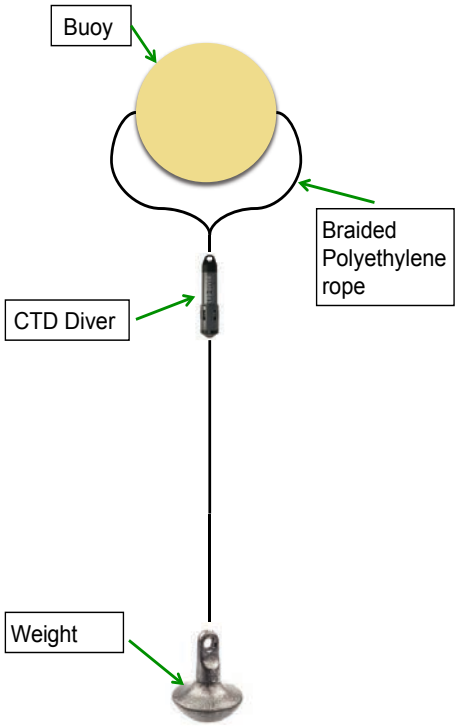
Fly-Over Sensing

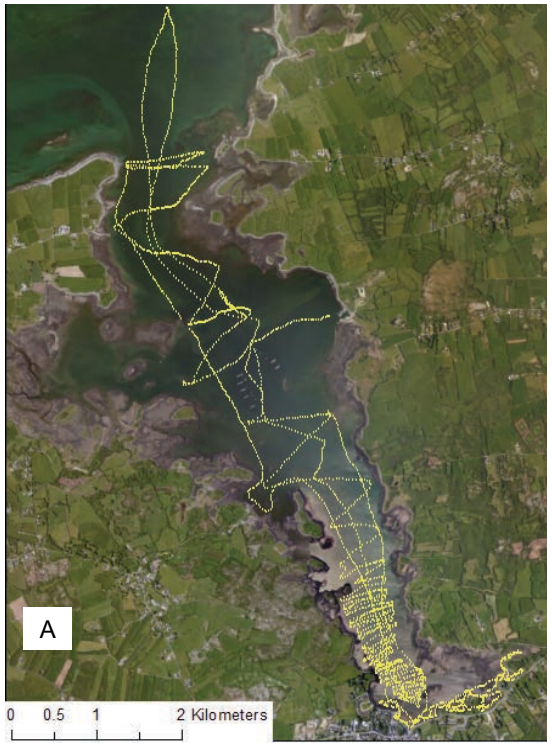


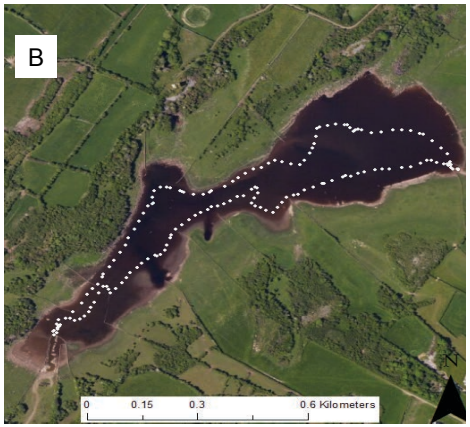


A) Sensor pod mounted on the wing strut of a Cessna 172 light aircraft; (B) The NCG sensor pod used to acquire data; (C). Flight paths for aerial flyovers of Kinvara bay and catchment area. K1 covers the inner bay while K2, K3 and K4 map the length of the bay from Kinvara to the mouth of the bay

In-Situ Sensing – Rig and Sampling Points

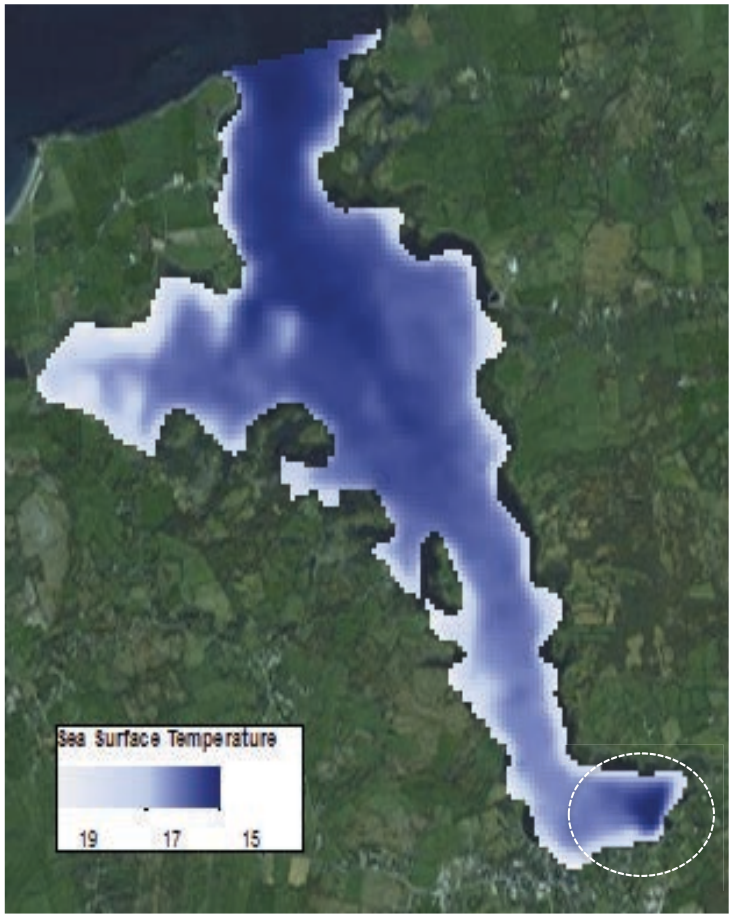


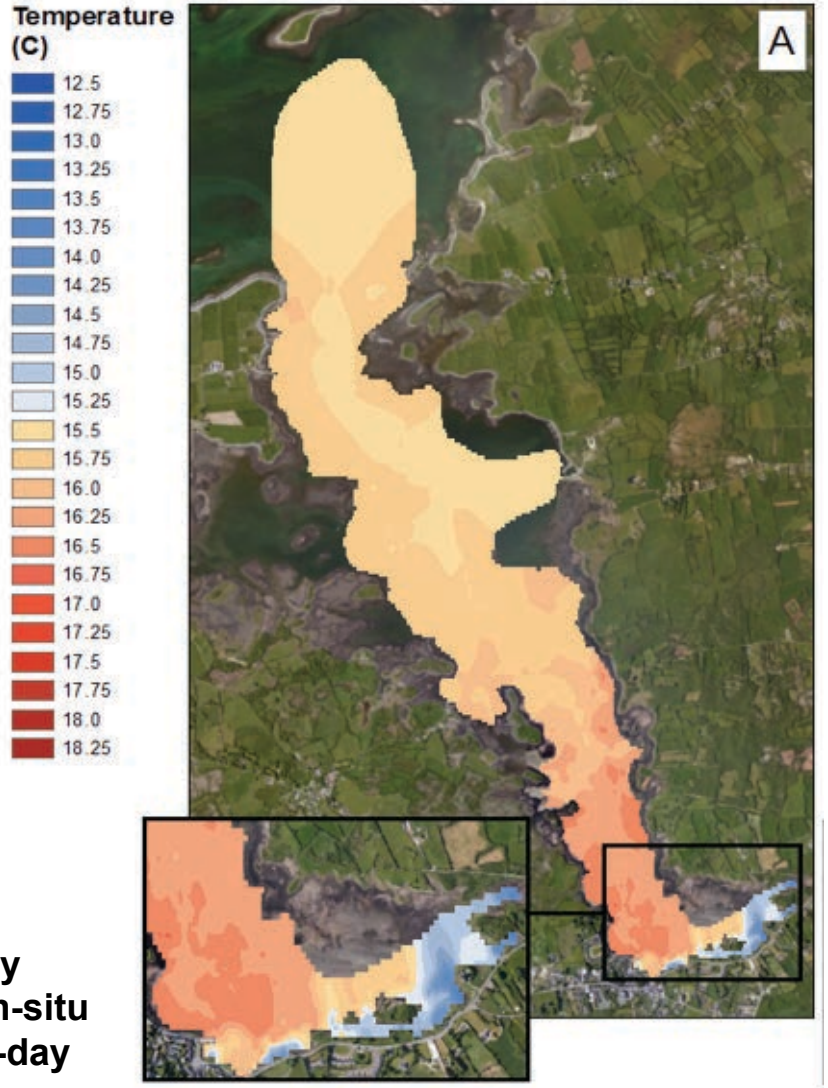




Location of in-situ data points collected over a four-day sampling campaign in (A) Kinvara Bay and (B) Cahergluassuan Turlough

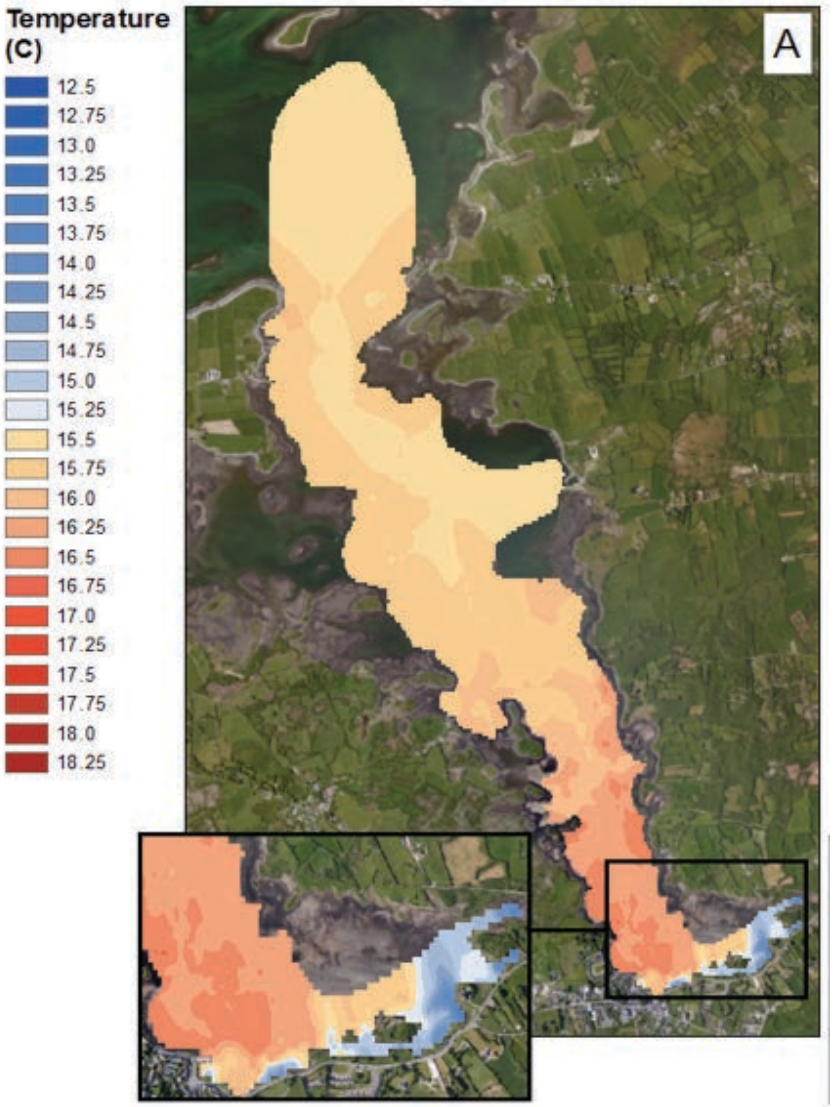
Comparing In-Situ and Satellite SST Measurements

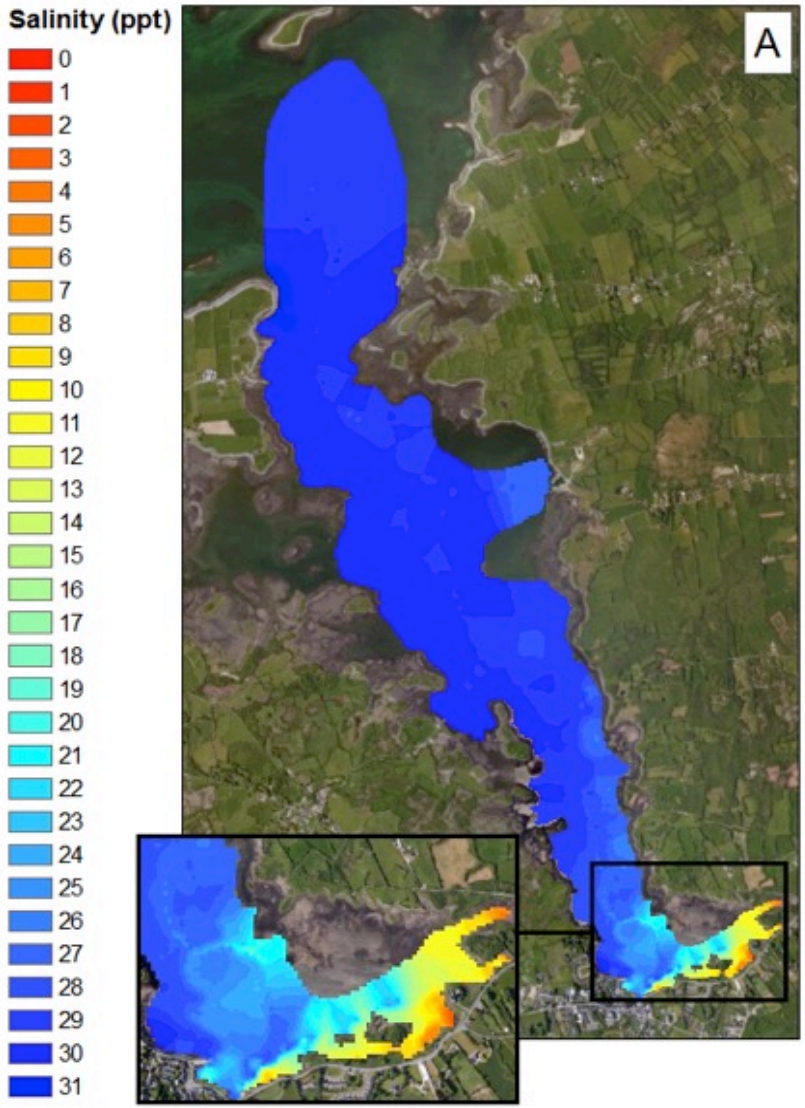




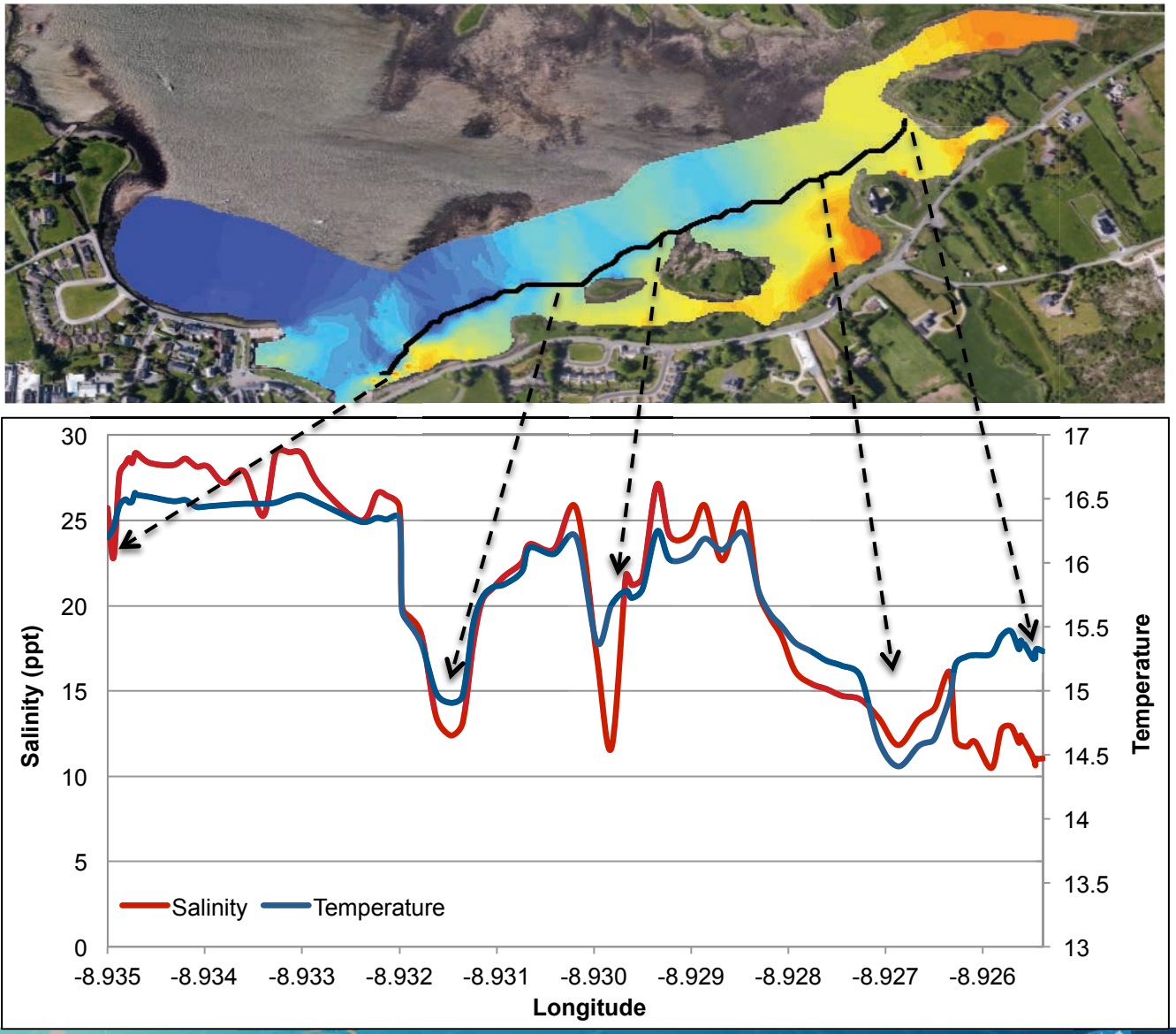
July 2013 sea surface temperature map of Kinvarra Bay generated from Landsat 8 Satellite sensing (left) and in-situ Sensing (right): Thermal imaging resolution 100 m; 16-day cycle (8-days with Landsat 7)

In-Situ Temp (L) vs Salinity (R)





Correlation of In-Situ Temperature and Salinity Measurements (East-West Transect)

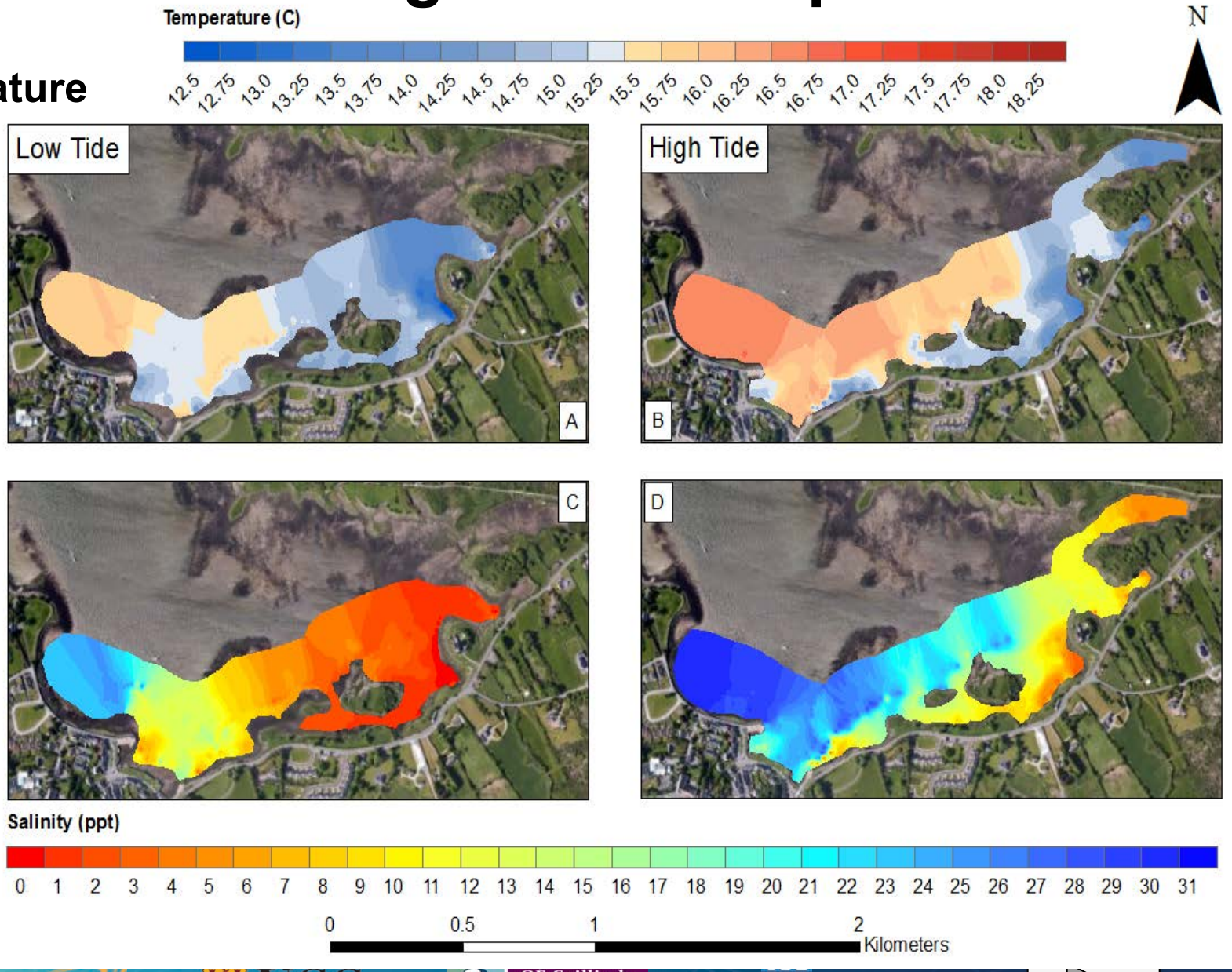


Temperature and salinity transect, stretching left to right from Kinvara pier (west) to Dunguaire castle (east); with salinity contour plot from in-situ bay survey

The effect of individual cold-water plumes is clearly evident in the salinity and temperature data.

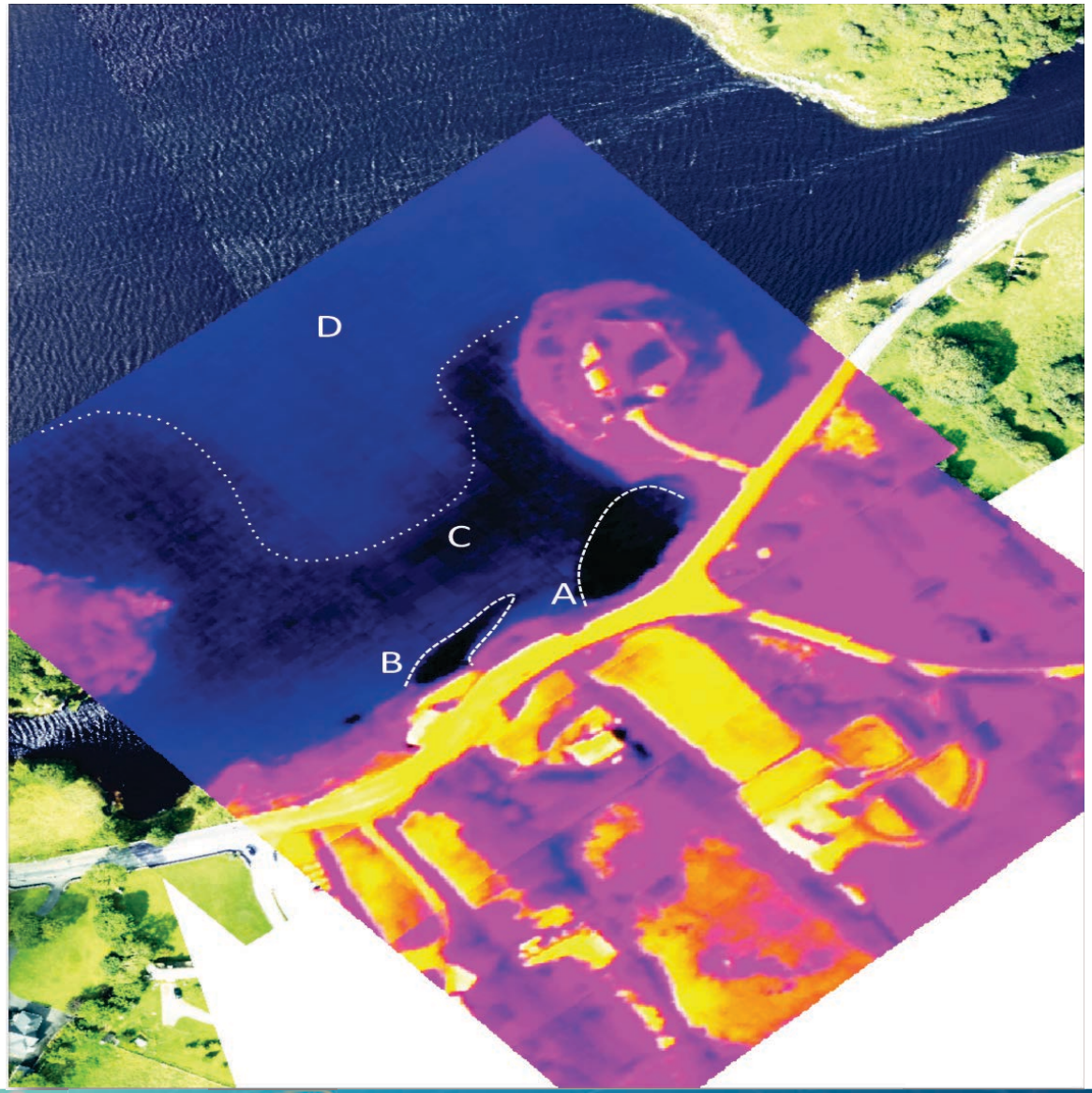
Low Tide/High Tide Comparison

Temperature



Salinity

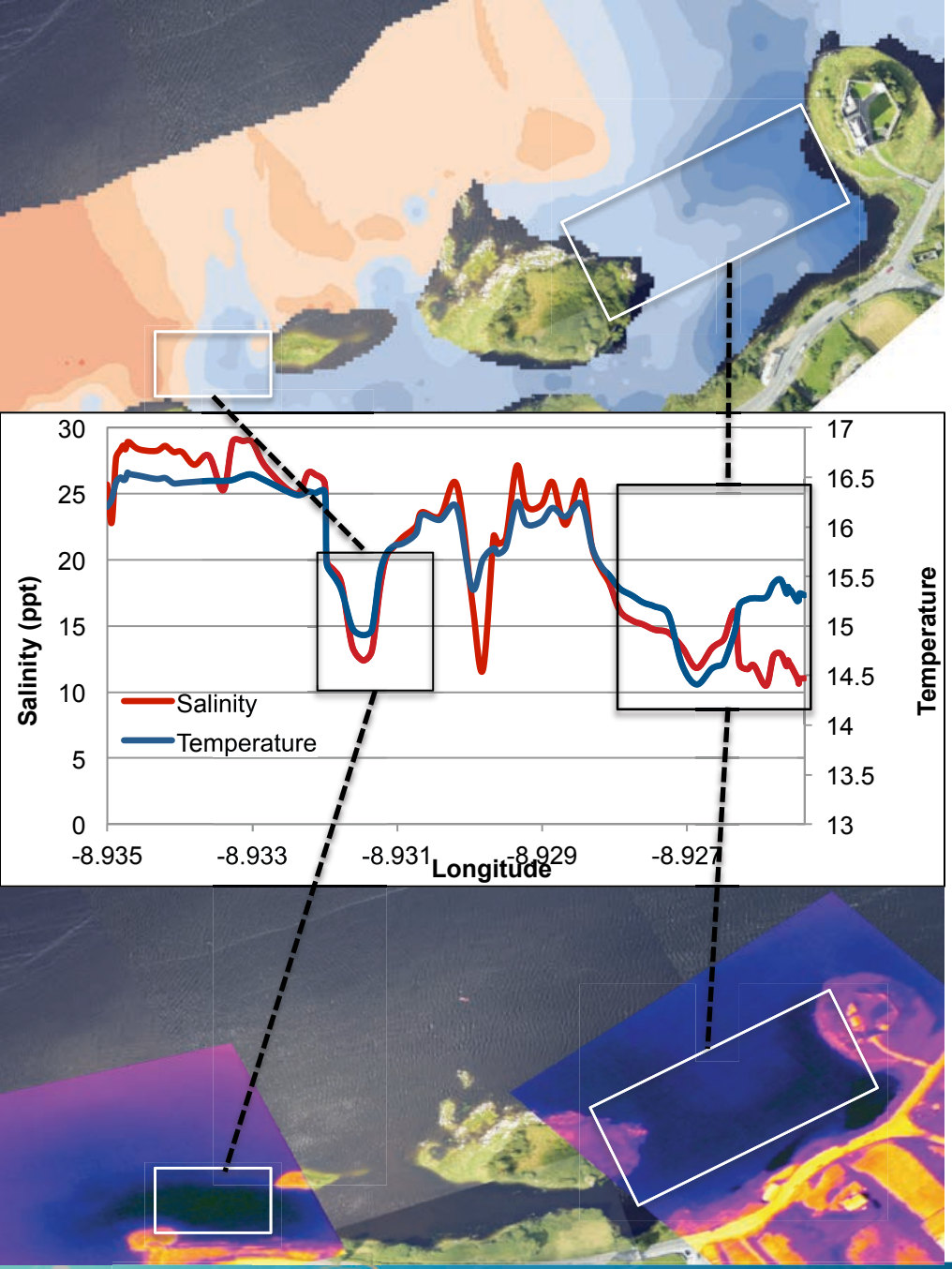
SST Multi-Spectral Imaging



Similar Patters in SST are obtained from MultiSpectral Flyover Measurements

Conclusion:
Satellite, Flyover, and In-situ Temperature Measurements are Highly Correlated

Salinity and temperature are highly correlated



Correlation between In-Situ Temperature (top)

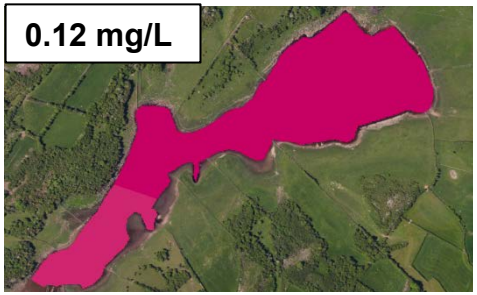
In-Situ Salinity & Temperature Transect (middle)

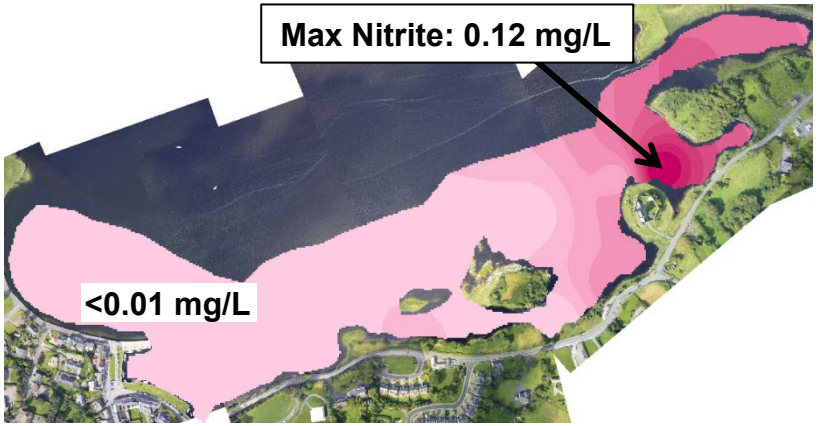
and Remote Thermal IR Fly-Over Data (bottom)

Nutrient Measurements

Nutrient levels at high tide

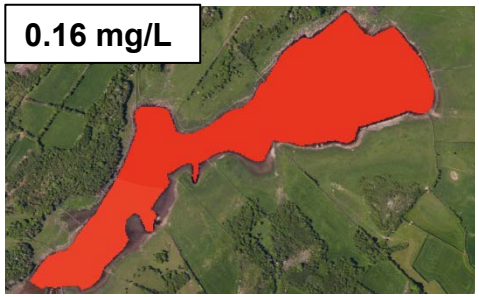
Nitrite

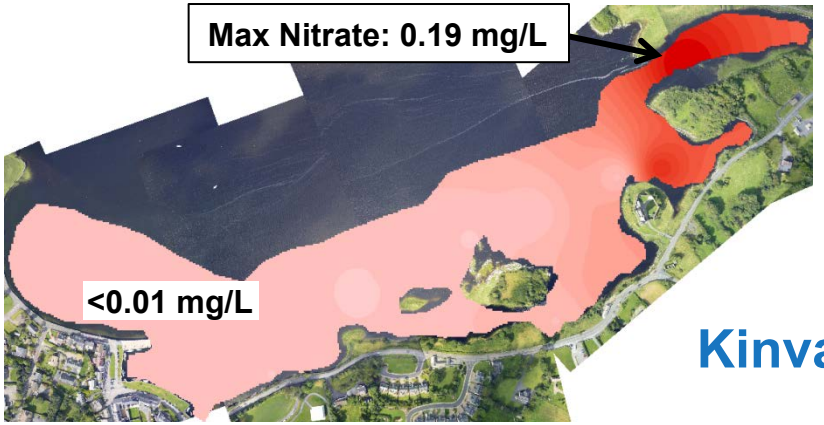




Caherglaussan Turlough

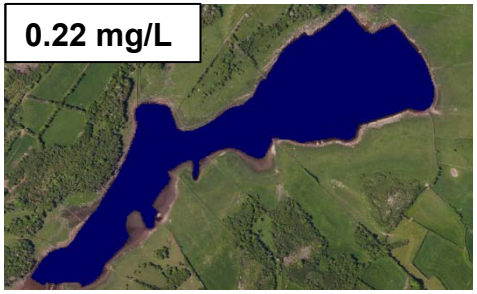
Nitrate

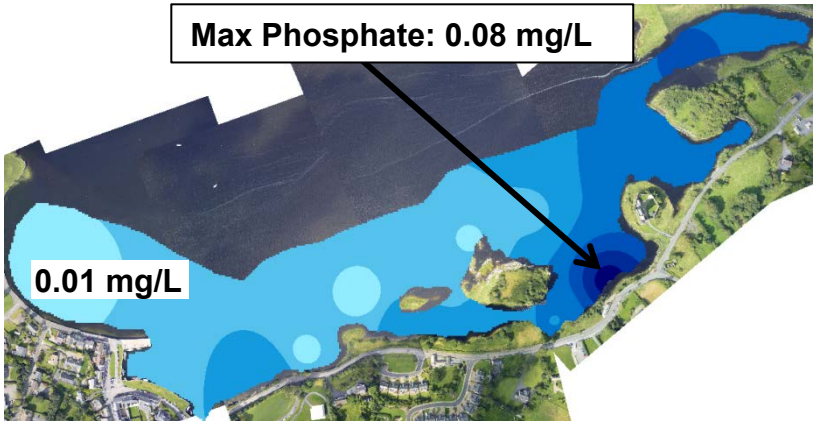




Kinvara Bay

Phosphate





Autonomous In-Situ Chemical Sensing

- Based on well established wet chemistry Colorimetric Methods
- Microfluidics used to implement methods
- Focus on Nutrients (phosphate, nitrate, nitrite, ammonia)
- Integrated reagents, standards, fluidics, electronics, power and communications
- Major deployments recently completed in Mediterranean and Artic

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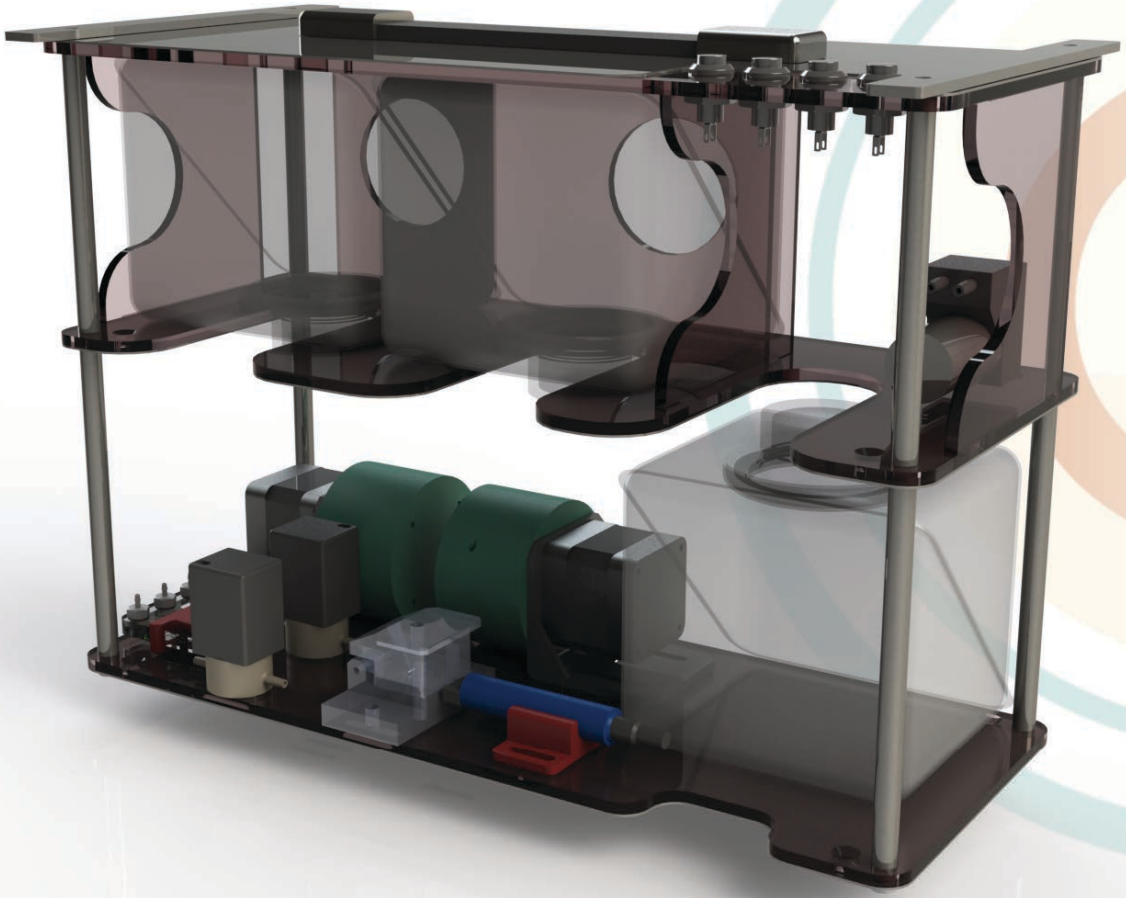
V2: Tested in The Institute of Microelectronics of Barcelona (IMB-CNM-CSIC) and Dublin City University (DCU)



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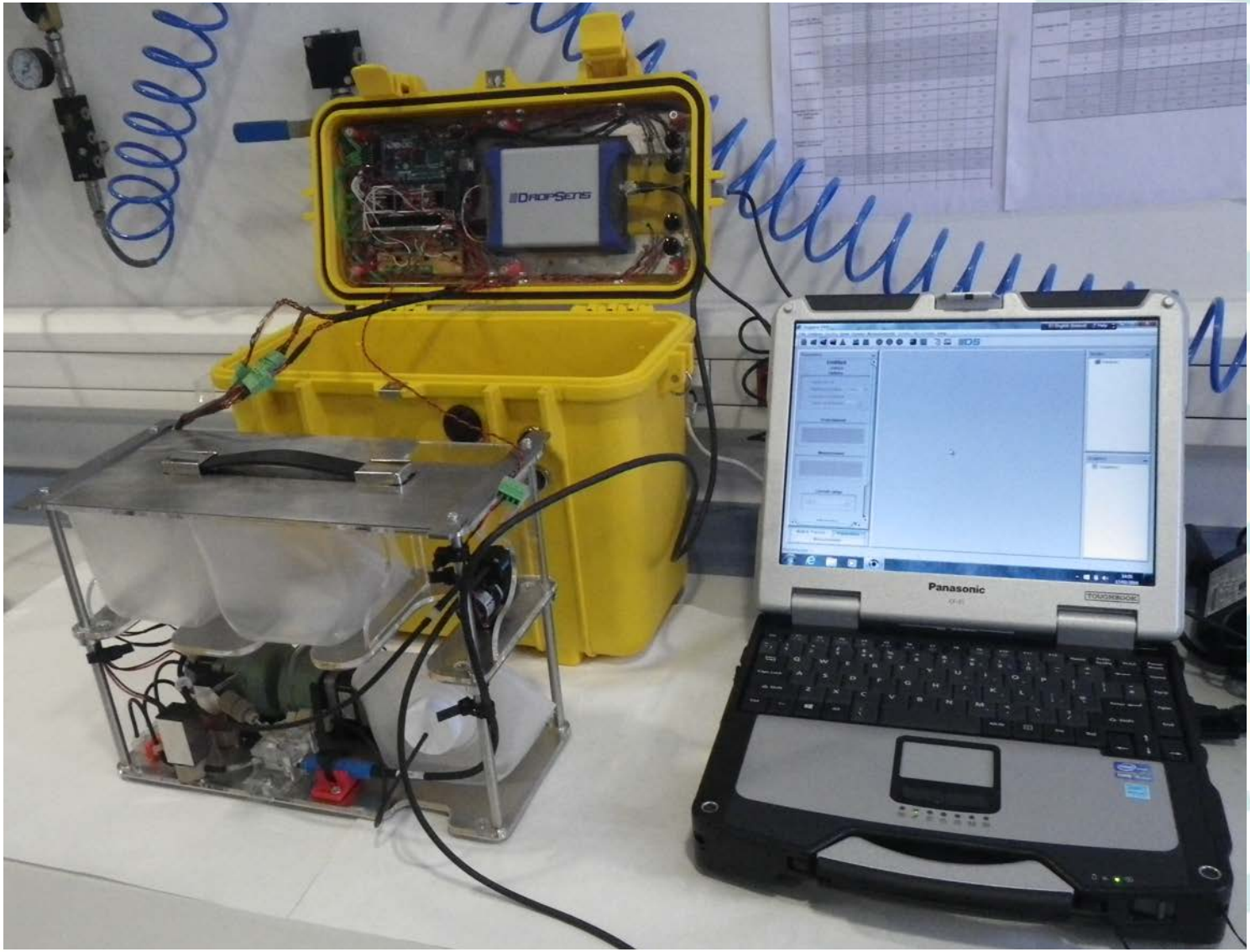

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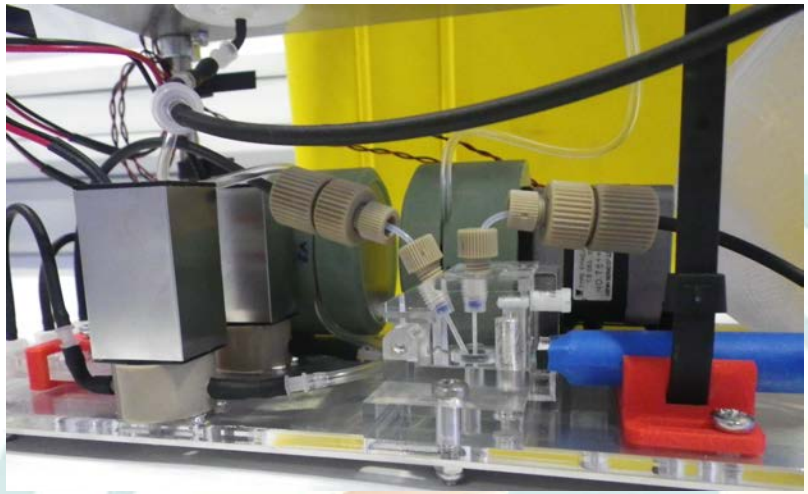

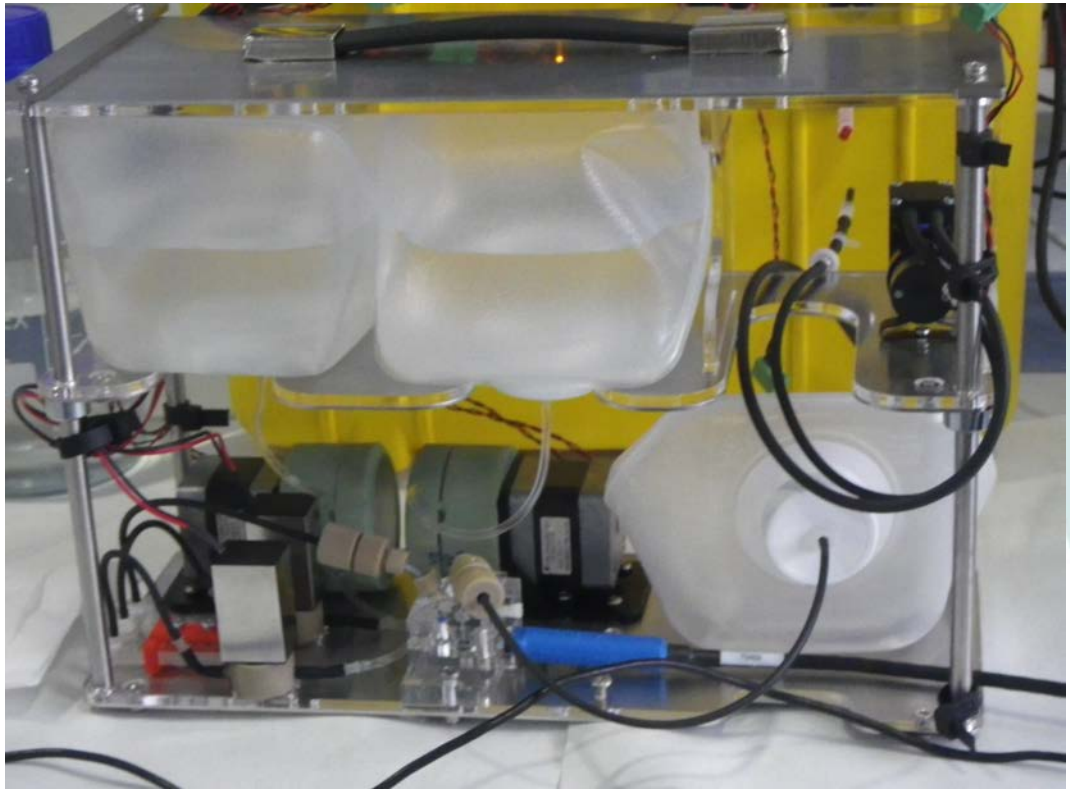

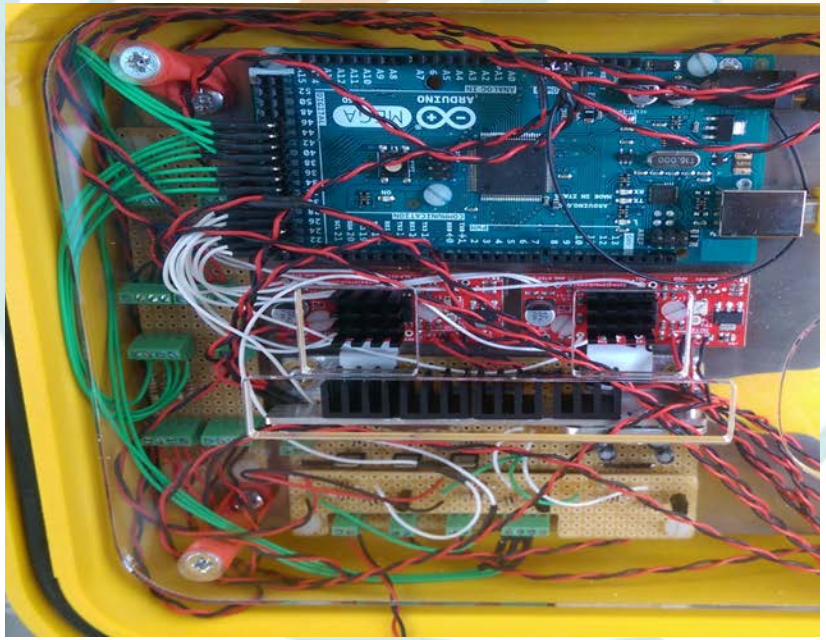

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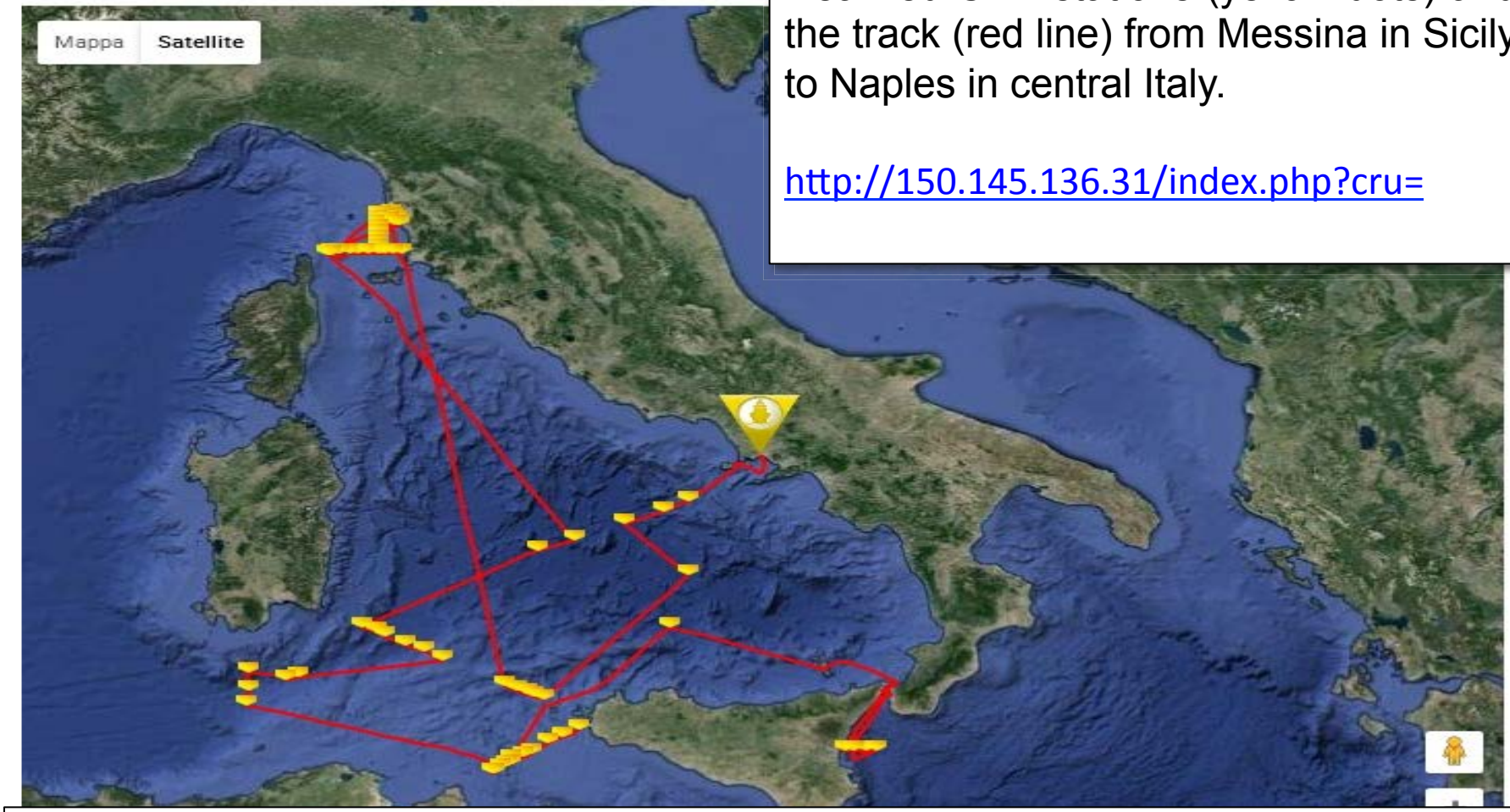
Ichnussa Research Cruise

Realized CTD stations (yellow dots) and the track (red line) from Messina in Sicily to Naples in central Italy.

http://150.145.136.31/index.php?cru=



Permission for activities planned in the cruise were given by Italian Coast Guard, Italian Navy and by Tunisian and French authorities when in their waters of competence

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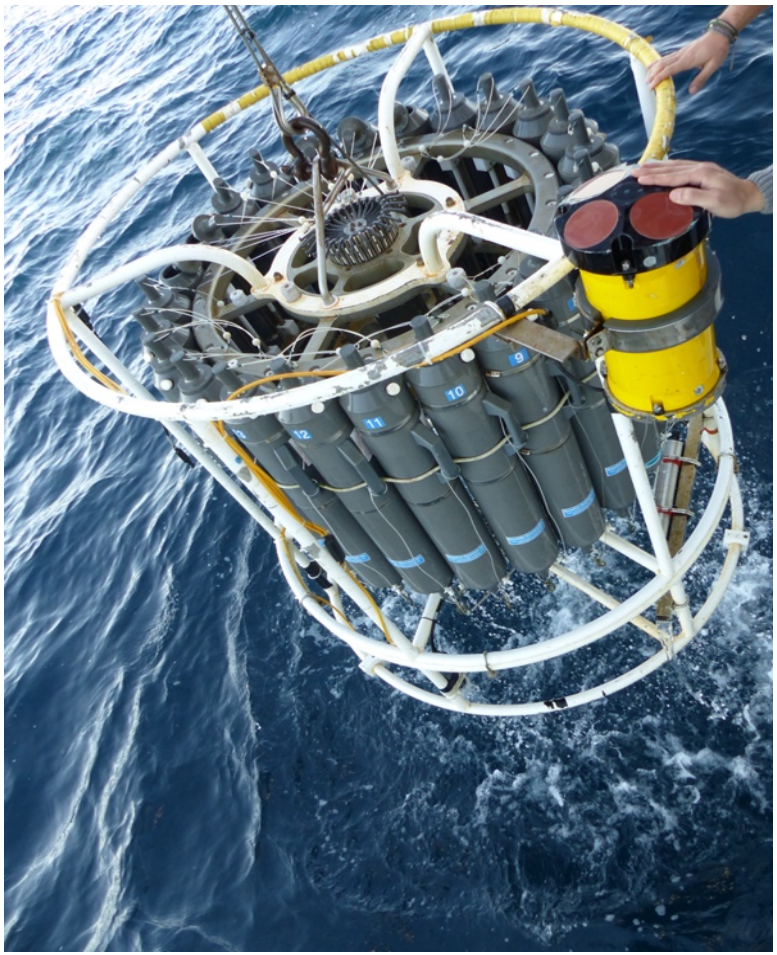

Sample Collection

- Water samples collected at depths using a 24 and 12 litres each Niskin bottles on an General Oceanic's rosette
- Multiparametric probe and other oceanographic instruments (CTD).
- Initially 20 litres sampled then after completion of suspended solid study 10 litres

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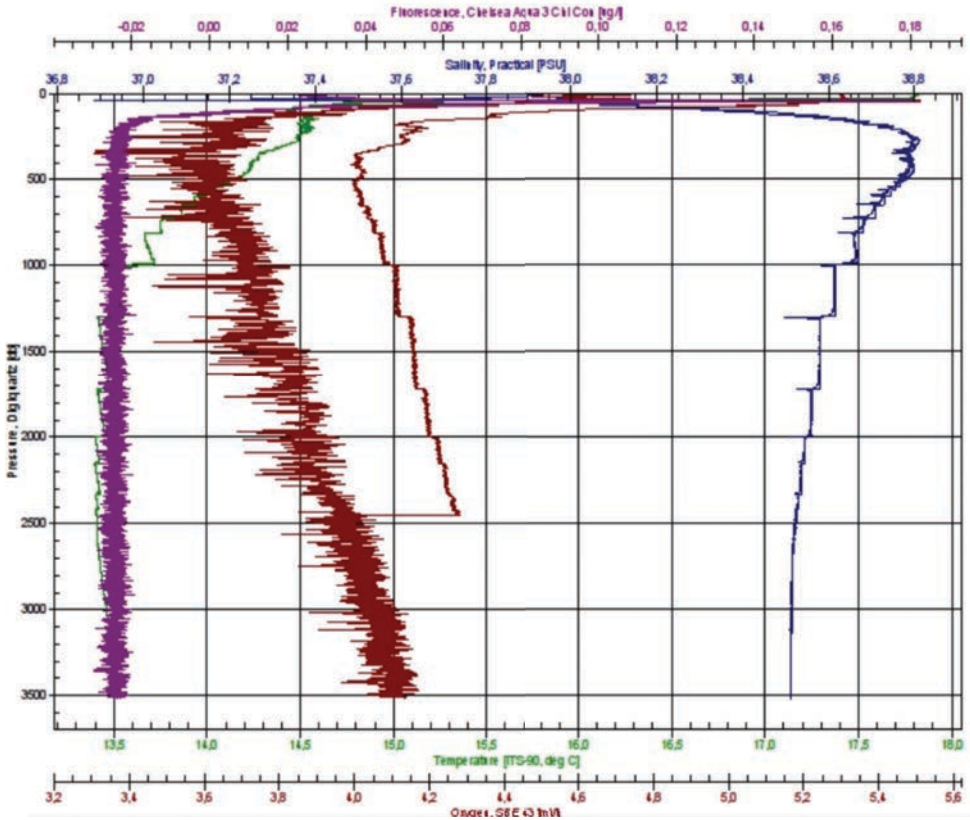
Station Name: Geostar

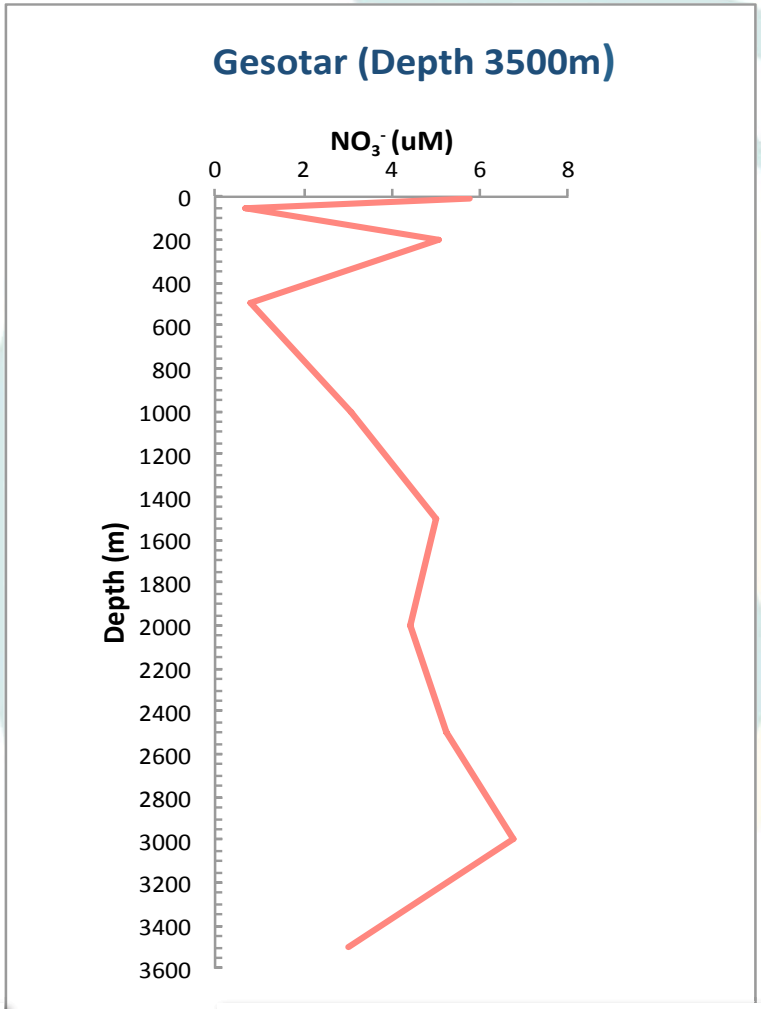
Position: 38.9165 N 13.299 E

Bottom depth: 3441 m

Sampling date: 2015-12-01 20:55:45



CTD and Chlorophyll profiles from surface to depth



Nitrate profiles from surface to depth (3500m)

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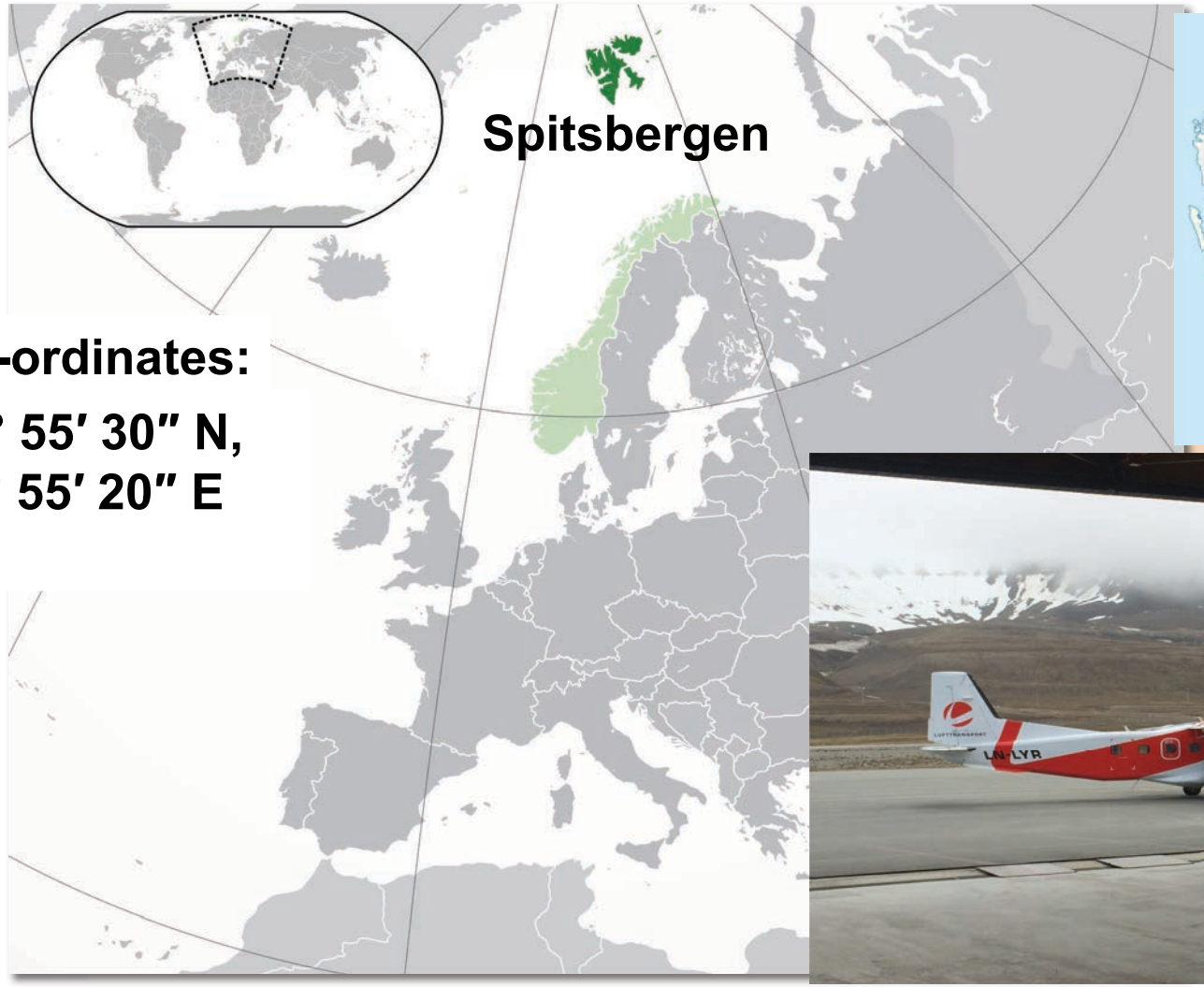
Ny-Ålesund-Svalbard



Co-ordinates:

78° 55′ 30″ N,
11° 55′ 20″ E

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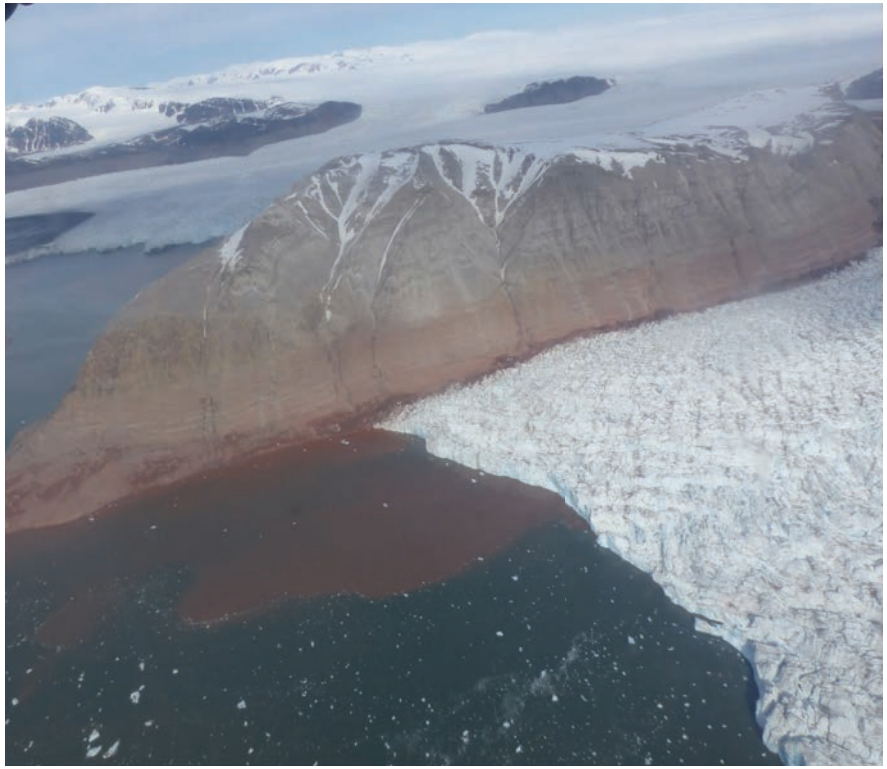
Glaciers at Ny-Ålesund



- **Arial pictures of Kongsvegen glacier.**
- **Samples were acquired and system deployed in front of the glacier**

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Sample Collection

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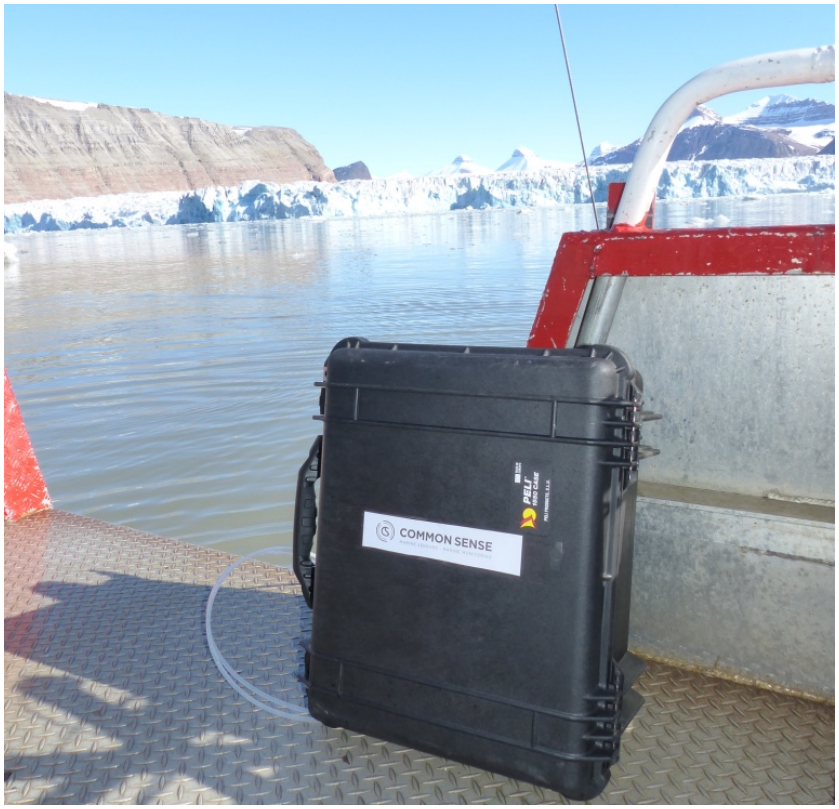
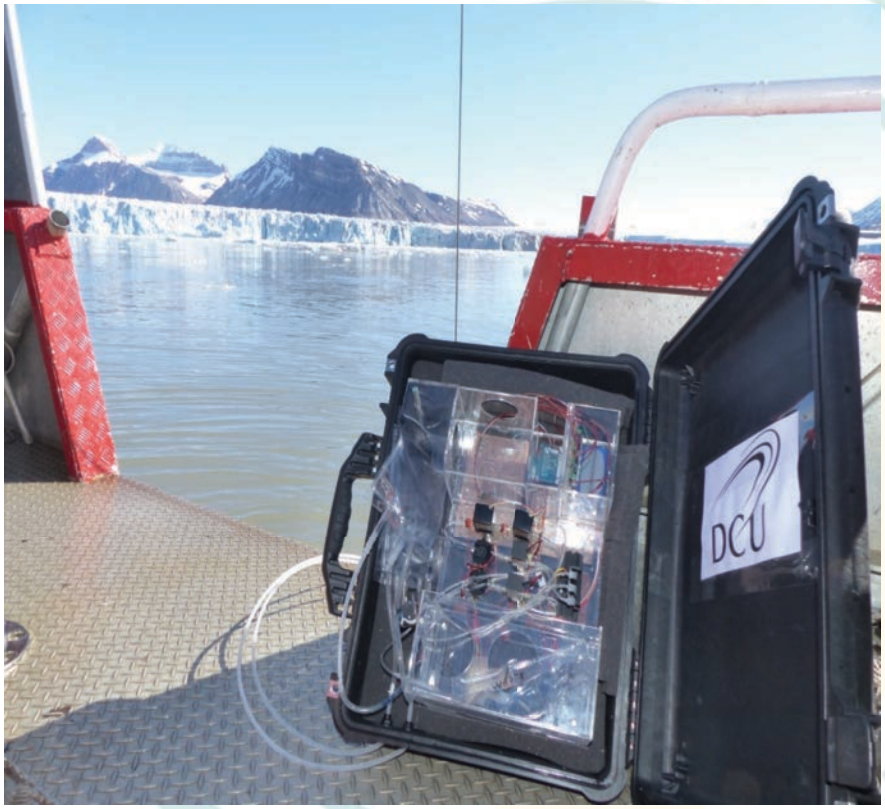
In-situ Measurements





CS Deployable system acquiring samples on board the MS Teisten beneath the of Kongsvegen glacier

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 614155.

Nutrient Challenge….

Participants March 2015

Registered Participants as of March 2015	
USDA Ag Research Service	Sea-Bird Coastal
Turner Designs	Open Photonics Inc.
ASA Analytics	Translume, Inc.
RATES	JAL Engineering
YSI, Inc.	Aquisure
Decagon Devices, Inc.	University of Illinois / MoboSense, LLC.
SYSTEA S.p.A.	Lumense, Inc.
Franklin Thompson	National Oceanography Centre
SUNY Binghampton	Environmental Monitoring Solutions, Ltd.
SubChem Sensor Systems, Inc.	Geekchitecture
T.E. Laboratories & Dublin City University	Katsujinken Foundation
CleanGrow, Ltd.	Water Canary
Blue Legacy International	Ayyeka
UCSD Biodynamics Lab	Real Tech
SRI International, Marine & Space Sensing Laboratory	

Current Status….

Field Test 1: Maumee River, Waterville, OH.
Set-up and Training: May 23-25
Field Deployment: May 26
Retrieval: June 28
Instruments Shipped to Vendors: July 7

Participants Selected for Final Verification Testing in 2016

Decagon Devices, Inc.	Real Tech	SYSTEA S.p.A.
National Oceanography Centre	Sea-Bird Coastal	T.E. Laboratories & Dublin City University

Field Test 2: Chesapeake Bay, Solomons, MD.
Prep for Field Deployment: July 16-17
Field Deployment: July 18
Retrieval: October 11
Instruments Shipped to Vendors: October 18

Field Test 3: Kaneohe Bay, HI.
Set-up and Training: October 3-5
Field Deployment: October 6

Thoughts….

- **Remote SST temperature can be used as a surrogate for in-situ salinity to track dynamics of fresh/sea-water mixing in the bay**
- **Assuming that the composition of each water type is relatively well conserved, then we can track the distribution of their chemistries in the bay e.g. track where the nutrients go with minimal in-situ measurements**
- **This is turn can dramatically change our sensing and sampling strategy**
  - Fewer in-situ measurements needed (Ground Truth system)
  - Much lower cost
- **Wide spatial and Temporal coverage**

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- NCSR, DCU
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- Research Partners – academic and industry
- EU Projects: NAPES, CommonSense, Aquawarn, MASK-IRSES, OrgBio

MASK
Project no: 269302
Materials and Advanced Sensor Knowledge Exchange

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COMMON SENSE
MARINE SENSORS - MARINE MONITORING

The COMMONSENSE consortium

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