



Malta Summer School 2018  
Operational Oceanography for Blue Growth



# Digital Age in Operational Oceanography *the cloud and consumer technology*

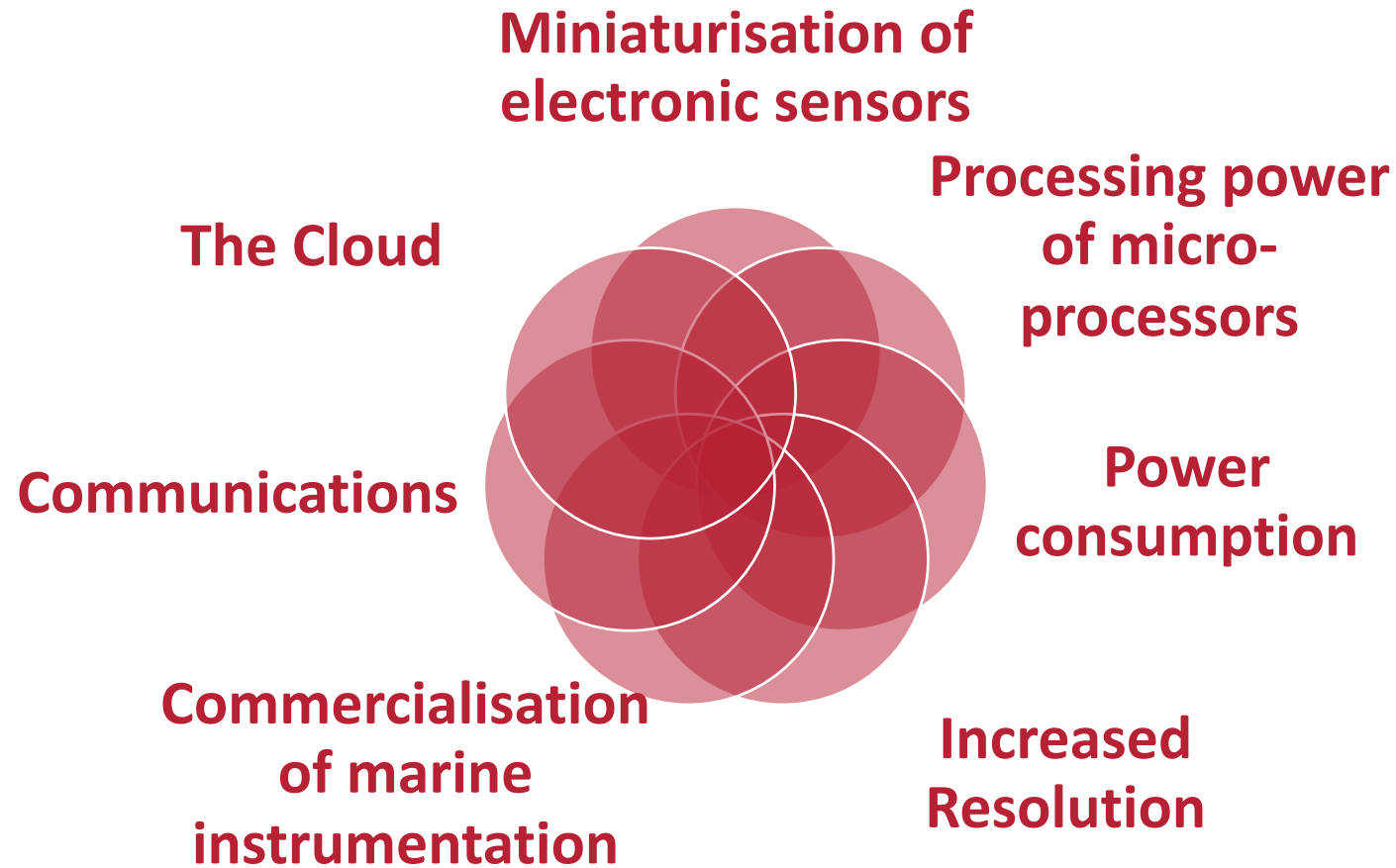
Graham Worley

Bangor University  
(thanks to David Mills)



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# Drivers for the development of Digital Operational Oceanography

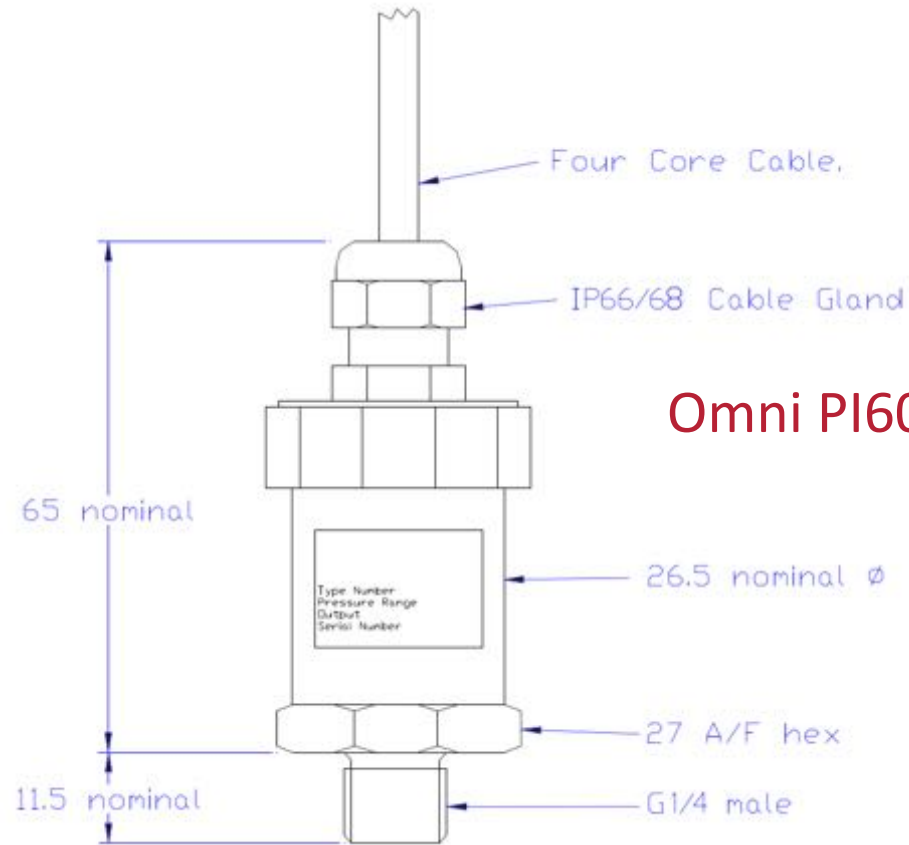


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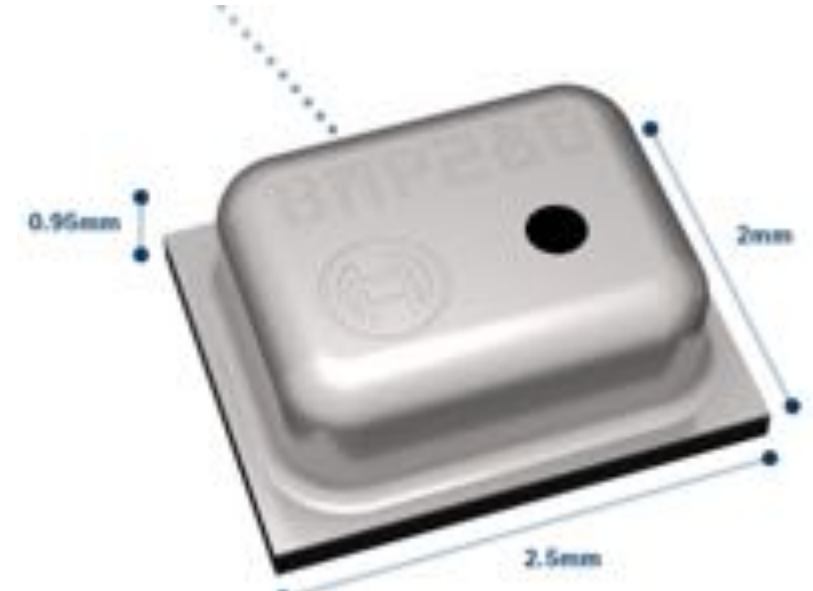
# Miniaturisation of sensors



Omni PI600 4-20mA Sensor



Bosch BMP280



# Processing power of micro-processors

MOS 6502 1980s

0.430 MIPS at 1.000 MHz



Qualcomm Snapdragon 800 2010s

(based on ARM Cortex A57)

~14,000DMIPS at 2.8GHz



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# Power consumption of micro-processors

Intel Pentium Pro 1990s  
541MIPS 50 Watts



Qualcomm Snapdragon 800 2010s  
(based on ARM Cortex A57)  
3-4 Watts  
SOC



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# Resolution

SeaBat T50-P / 7125

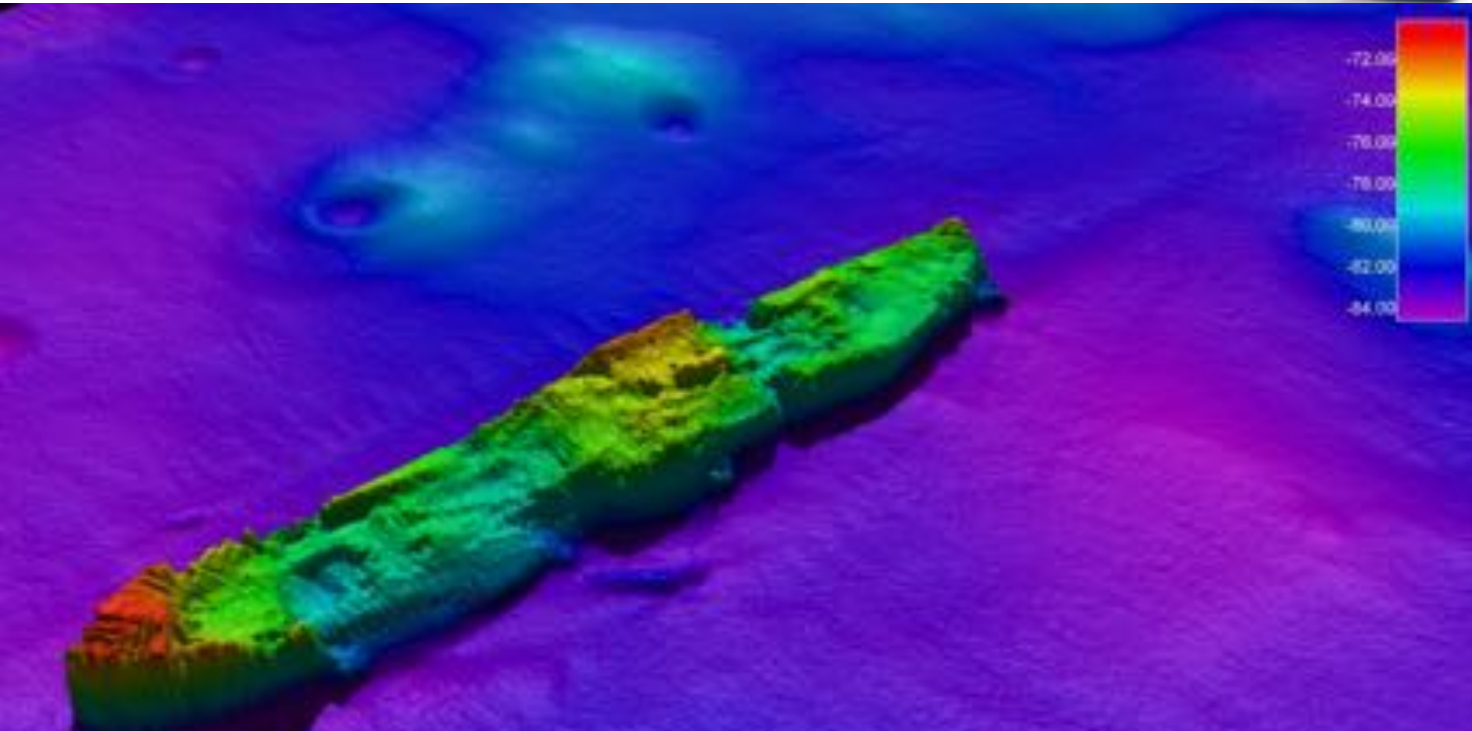
512beams 0.5x1 degree

300Gbytes of data a day

<0.5m grid



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# Communications

1990s Telephone Modem 9600 bits/s



X25 Leased Line 2400 – 2048k bit/s



2010s

5-12Mbits/s



2400bits/s

100Mbit/s to  
10Gbit/s



400kbit/s



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# Cloud Computing



## Software As A Service (SAaS)

Pre-installed ready-to-use software:

- Microsoft Office 365
- Adobe Creative Cloud

Combines storage, computing and software as one service

## Infrastructure As A Service (IAaS)

Public cloud: On-demand Pay as You Go

Storage – massively scalable

Compute – 1 to thousands of cores

Automation

Scalability

Orchestration



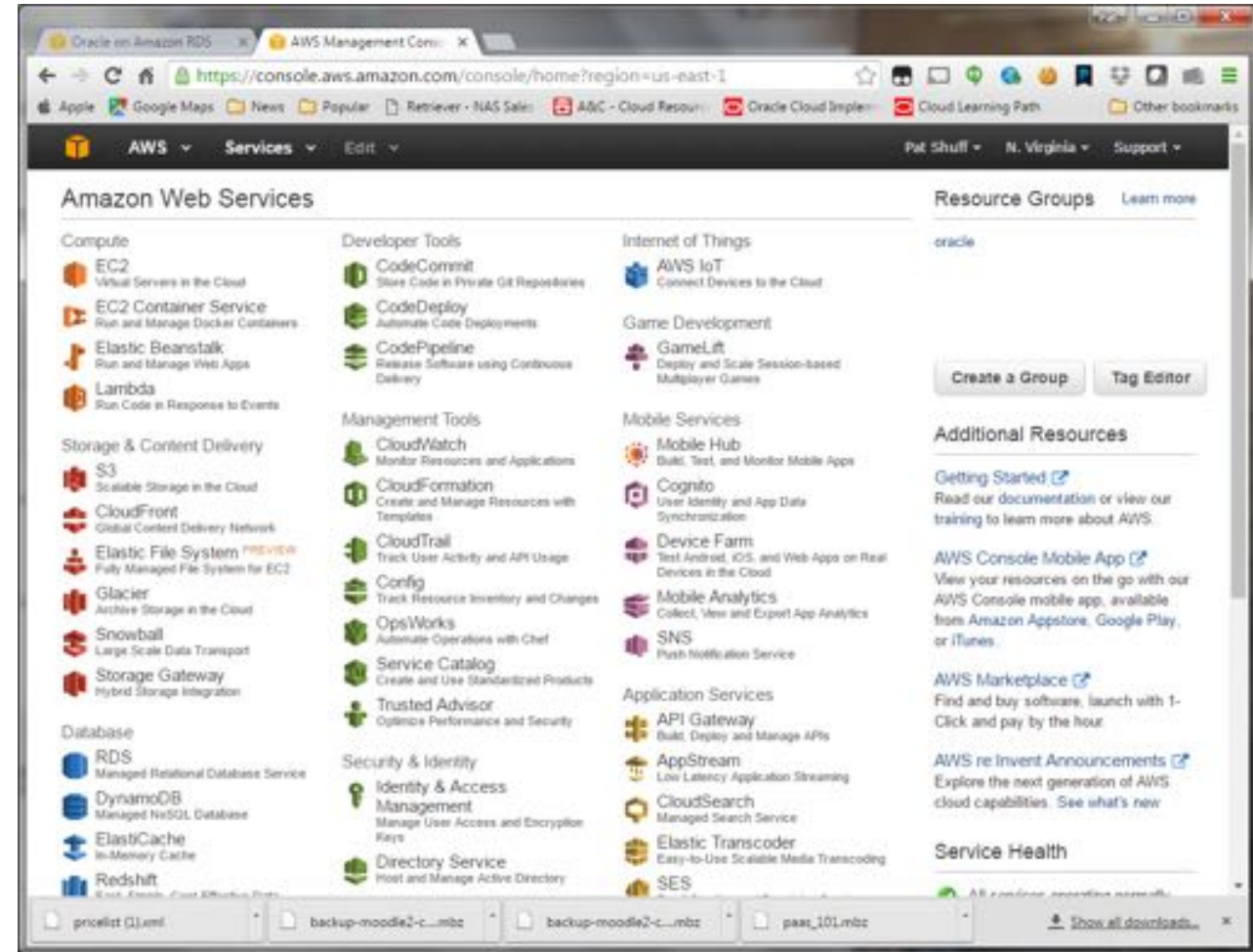
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# Cloud Computing – Lightweight scalability

No more heavy machines....point and click deployment...



# Cloud Computing – Storage

Scale – 1byte to infinity

Cost – 360 USD per Tbyte per annum

Accessibility

Security / Encryption

Programmability - S3 Application

Programming Interface



Amazon S3



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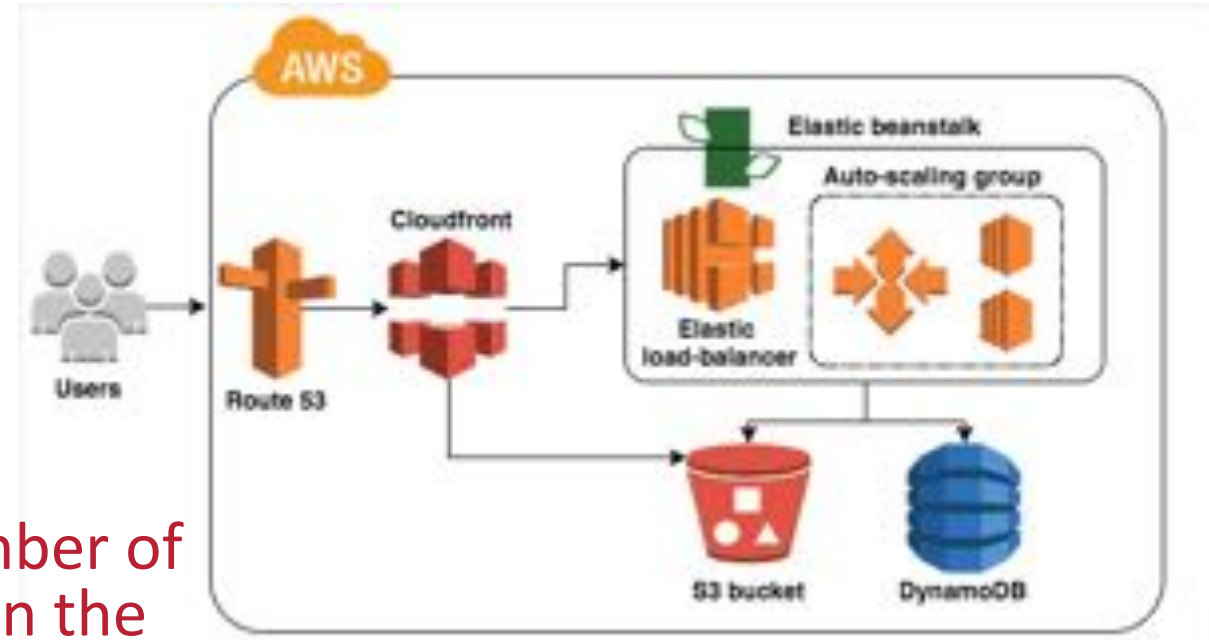


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# Cloud Computing – Data Delivery

## AWS Elastic beanstalk

- Orchestration
- Auto-scaling
- Fault-tolerant
- Geo-localised
- Can serve any number of people anywhere in the world.
- No longer constrained by power of one or two servers in the laboratory.





# Cloud Computing – Compute Resource

## Supercomputing - HPC in the cloud for modelling



1 to many traditional virtual machines

Custom machine images (AMIs)

CfnCluster – AWS CloudFormation Cluster



15 billion forecast per day via AWS



AWS EC2 Powers NETFLIX

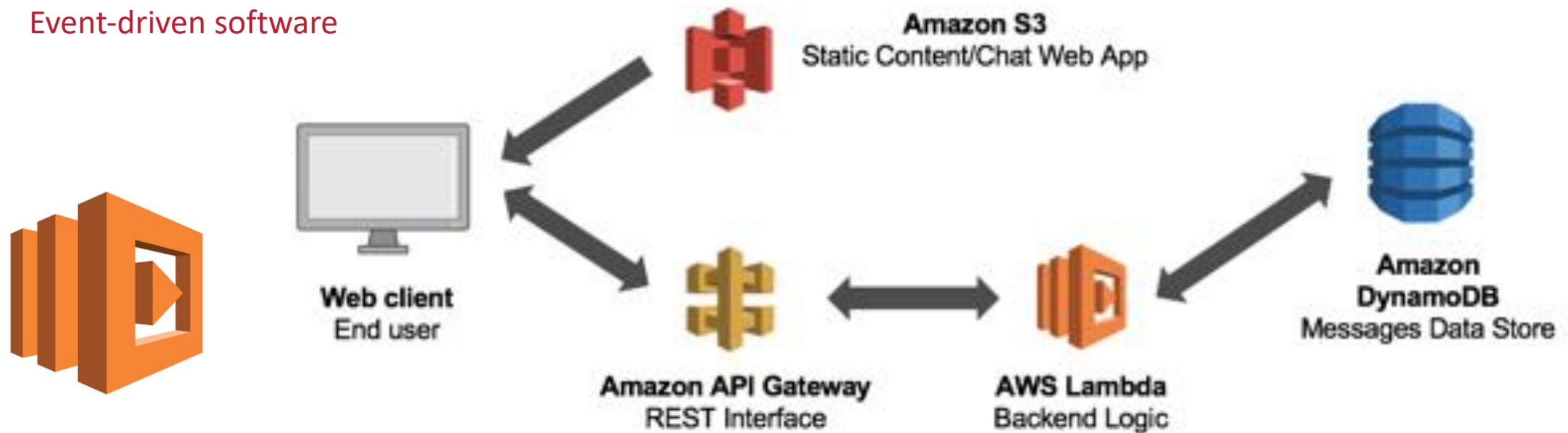
# Cloud Computing – Compute Resource

## Functional Computing - Lambda Functions

Virtual Machines – High idle-time

Lambda functions – No idle-time charging

Event-driven software

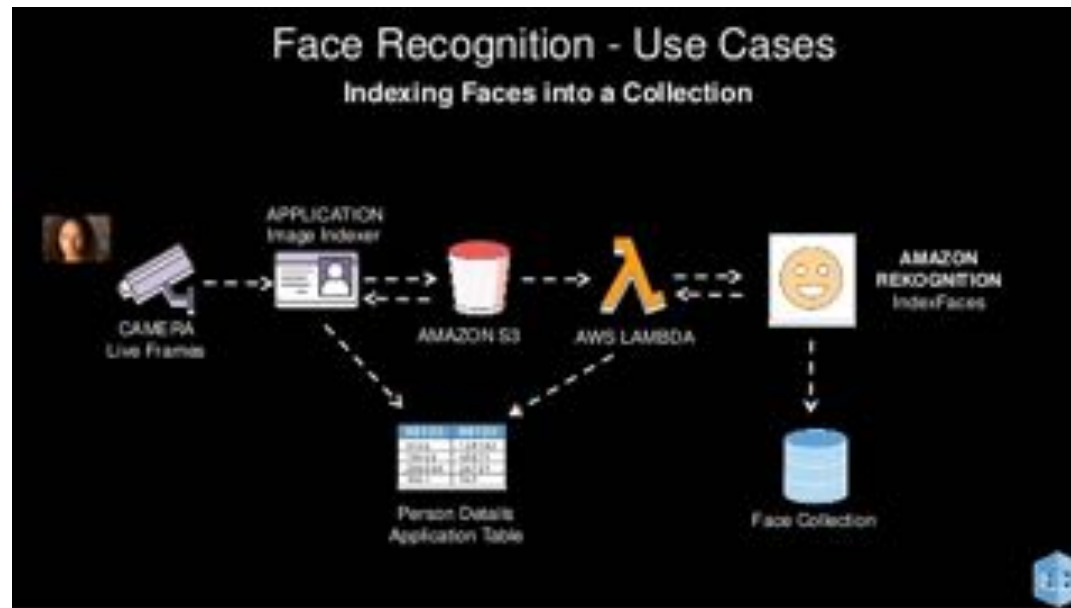


# Cloud Computing – Compute Resource

## Analytical Computing

Tailored software services powered by virtual machines and lambda functions

Machine Learning – On-demand regression analysis on a massive scale



Re-purpose face recognition services for feature detection?

- Detection of fronts
- Wave / Surface current analysis
- Beach morphology





# Cloud Computing – In summary

**Great for prototyping and production workloads**  
**Delete when done**



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# SEACAMS Relocatable Observatory

Relocatable OSIL Fulmar Buoy  
4G and Iridium Coms  
Multi-parameter



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# SEACAMS Relocatable Observatory

- 6km North-east of Llandudno





# SEACAMS Relocatable Observatory

## Sub-Surface Instrumentation

- Nortek AWAC
- Campbell Scientific Turbidity Sensor
- Teledyne Acoustic Modem



## Surface Instrumentation

- RBR Maestro CTD (conductivity, temperature, depth, chlorophyll,
- Teledyne Acoustic Modem
- 3G Modem
- Rockblock Iridium Modem
- AirMar Wind Vane



# SEACAMS Relocatable Observatory

# Campbell CR6 Logger



- Assembles data frames
- Delivers to Amazon Web Services via 3G / Iridium
- IoT Internet of Things?

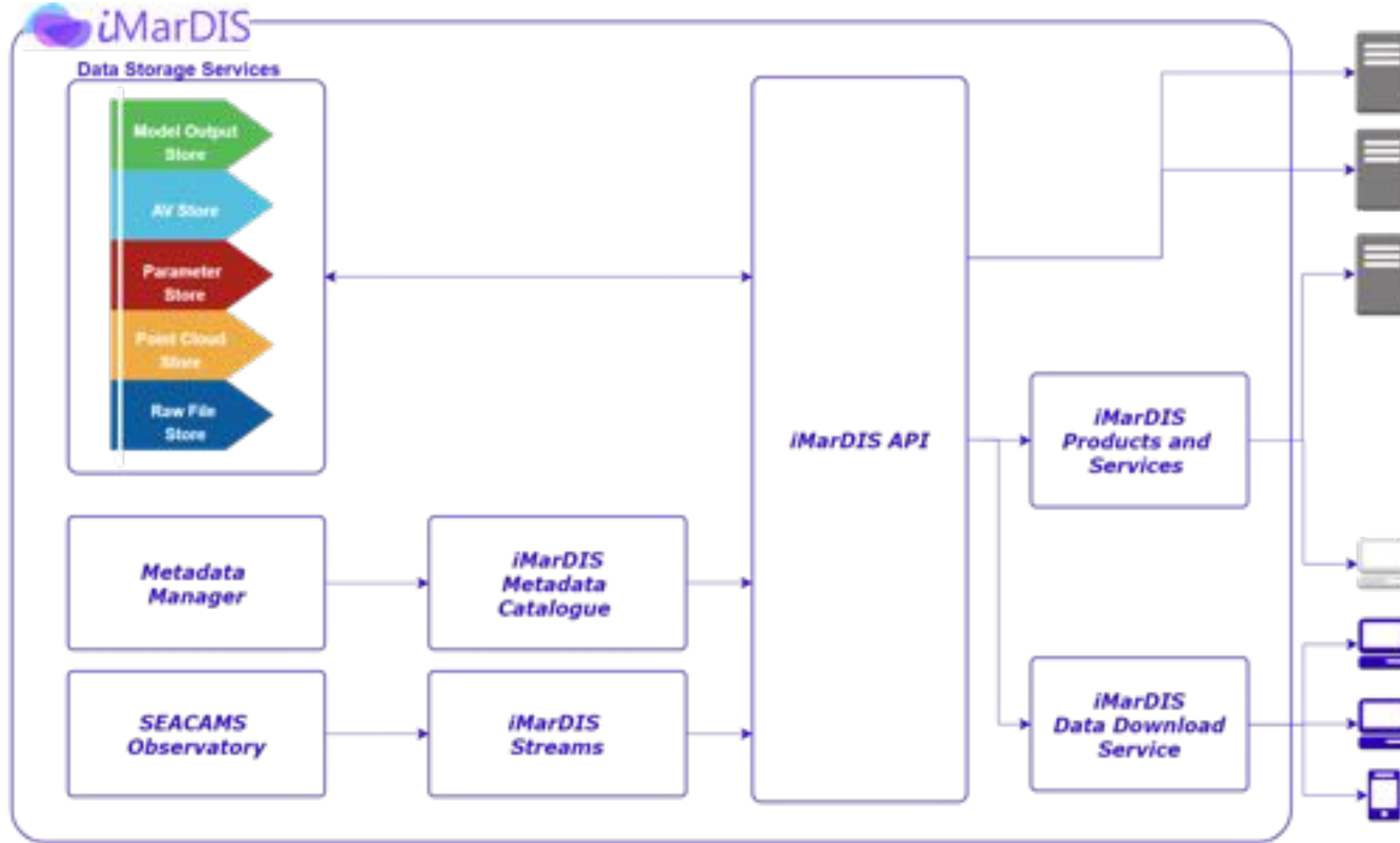


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# SEACAMS Relocatable Observatory



iMarDIS  
Integrated Marine  
Data and  
Information System

Cloud-based  
infrastructure to  
handle and share  
marine data





# SEACAMS Relocatable Observatory

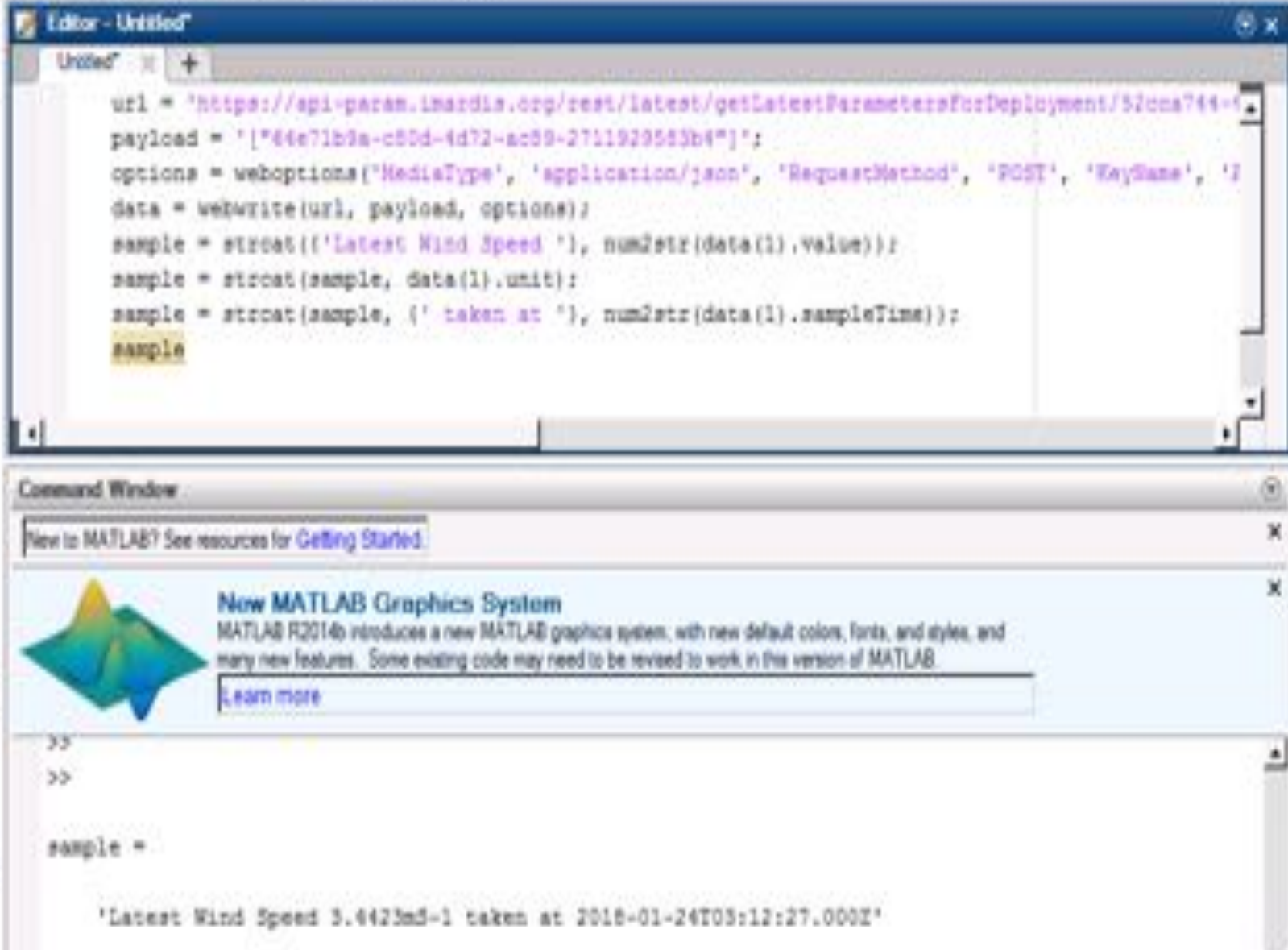
<http://www.imardis.org/observatory-live>

Latest values for selected stations: [IMARDIS] [Seaplane] [IBAC] [IBAC]

Variable	Value	Unit	Received Time
Start-up time	01:14		2018-07-07 01:14:00
Air/Water Temperature	20.00C		2018-07-07 01:14:00
Compass Temperature	20.00C		2018-07-07 01:14:00
Water Level	0.00m		2018-07-07 01:14:00
GPS Latitude	53.175000N		2018-07-07 01:14:00
Water pH	8.000000		2018-07-07 01:14:00
Salinity	35.000000		2018-07-07 01:14:00
Weather			
Barometric Pressure	1013.00hPa		2018-07-07 01:14:00
Wind Direction (True)	180.00degrees		2018-07-07 01:14:00
Wind Speed	0.00m/s		2018-07-07 01:14:00
Water			
Conductivity	43.000000		2018-07-07 01:14:00
Relative Water Pressure	1013.00hPa		2018-07-07 01:14:00
Turbidity	0.00NTU		2018-07-07 01:14:00
Height of Water Column	0.00m		2018-07-07 01:14:00
Speed of Sound through Water	1500.00m/s		2018-07-07 01:14:00
IBAC General			
Analogous Channel 1	0.000000		2018-07-07 01:14:00
Mean Analogous Channel 1	0.000000		2018-07-07 01:14:00
Number of IBAC Data	0.000000		2018-07-07 01:14:00
Cell Height	0.000000		2018-07-07 01:14:00
Number of IBAC	0.000000		2018-07-07 01:14:00
IBAC Waves			
1st Significant wave height (spectral dominant)	0.00m		2018-07-07 01:14:00
Peak Mean of the 1st largest waves in record	0.00m		2018-07-07 01:14:00
1st Wave period (peak period)	0.00s		2018-07-07 01:14:00
Mean wave direction (weighted average)	0.00degrees		2018-07-07 01:14:00
1st Wave period	0.00s		2018-07-07 01:14:00
IBAC Current			
Current	0.00	m/s	2018-07-07 01:14:00
Direction	0.00	degrees	2018-07-07 01:14:00
Velocity 1	0.00	m/s	2018-07-07 01:14:00
Velocity 2	0.00	m/s	2018-07-07 01:14:00
Velocity 3	0.00	m/s	2018-07-07 01:14:00
Amplitude 1	0.00	m/s	2018-07-07 01:14:00
Amplitude 2	0.00	m/s	2018-07-07 01:14:00
Amplitude 3	0.00	m/s	2018-07-07 01:14:00



# SEACAMS Relocatable Observatory




The image shows a MATLAB environment. The Editor window displays a script that uses the `webwrite` function to fetch data from a REST API. The Command Window shows the execution of the script, resulting in a string that concatenates the fetched data with a timestamp.

```
url = 'https://api-param.inardie.org/rest/latest/getLatestParametersForDeployment/52cna744-1';  
payload = '{"64e71b3a-c80d-4d72-ac89-2711929583b4"}';  
options = weboptions('MediaType', 'application/json', 'RequestMethod', 'POST', 'KeyName', '');  
data = webwrite(url, payload, options);  
sample = strcat(['Latest Wind Speed ', num2str(data(1).value)]);  
sample = strcat(sample, data(1).unit);  
sample = strcat(sample, (' taken at '), num2str(data(1).sampleTime));  
sample
```

Command Window:

New to MATLAB? See resources for [Getting Started](#).

 **New MATLAB Graphics System**  
MATLAB R2014b introduces a new MATLAB graphics system, with new default colors, fonts, and styles, and many new features. Some existing code may need to be revised to work in this version of MATLAB.  
[Learn more](#)

```
>>  
>>  
  
sample =  
  
'Latest Wind Speed 3.4423m/s-1 taken at 2018-01-24T03:12:27.000Z'
```



# Similar Deployment – CEFAS SmartBuoy

## SmartBuoy – Near surface instruments



Multichannel  
logger - CTD, OBS,  
O<sub>2</sub>

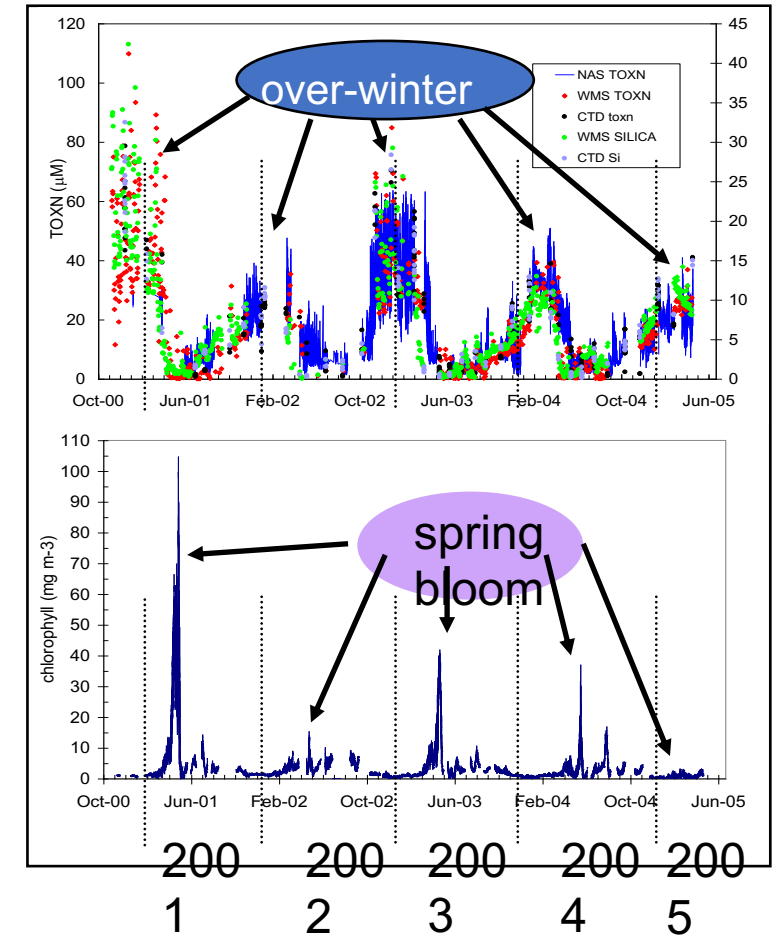
Fluorometers



In situ  
nitrate  
analyser



Water  
sampler



# Intelligent Sensors

- Sensors with micro processors
- Internet of Things
- File their own data – Sensor Web Enablement  
SensorML describes the sensor and the data enables IoT data deposit
- Many standards – JSON over REST will eventually dominate



# Autonomous Vehicles – Surface / Sub-Surface

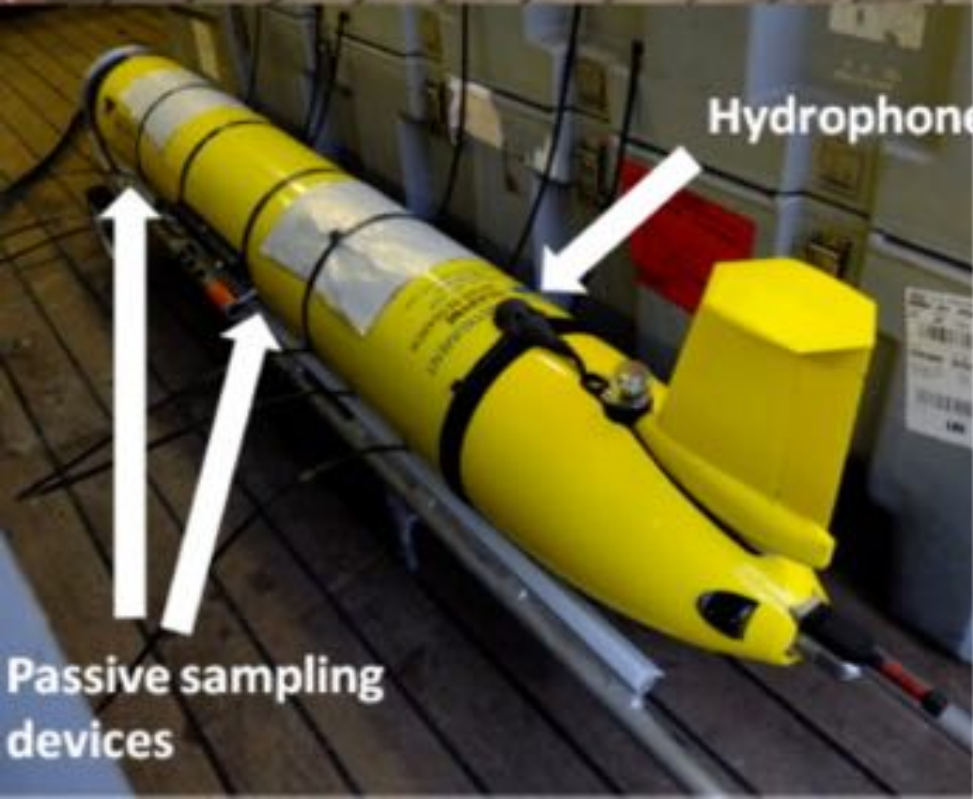


## Advantages

- Operate in adverse conditions
- High spatial and temporal resolution
- Cost efficiency (?)

## Issues

- Sensor calibration and validation
- Requires additional data/information from other sources (ships, moorings)
- Qualitative vs quantitative observations



Assessing the potential of autonomous submarine gliders for ecosystem monitoring across multiple trophic levels (plankton to cetaceans) and pollutants in shallow shelf seas. Suberg et al., 2014.  
<https://doi.org/10.1016/j.mio.2014.06.002>





# Semi-Autonomous Vehicles - Airborne

Instrumented drones - LIDAR



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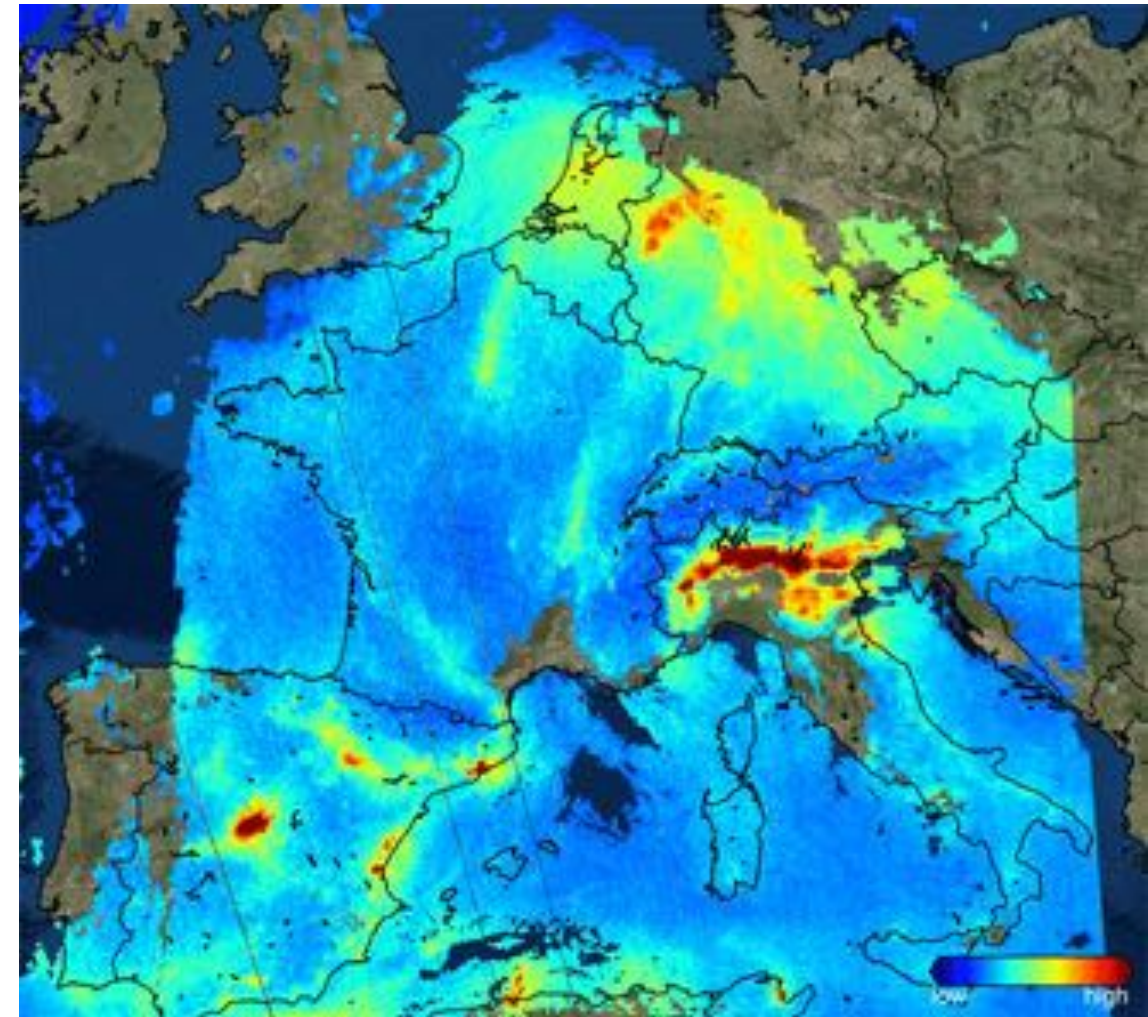


# Remote Sensing

*continual evolution*



Copernicus Sentinel Data 2017 NO<sub>2</sub>



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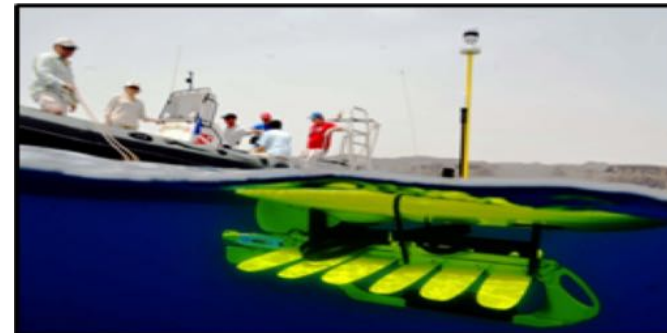
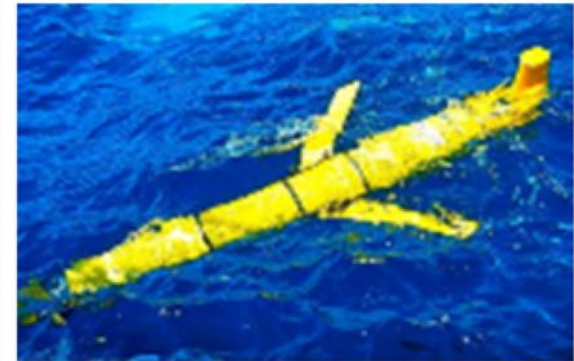


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# The Future

Ships are expensive



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# UK-IMON International Workshop on New Monitoring Technologies:



## Themes

- Autonomous systems
- Conventional systems
- Sensors
- Other data acquisition systems



VoOp



## How can we reduce the cost of making observations ?



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# UK-IMON -Autonomous platforms ranking

Platform name	Score	TRL
AUV Class #1 (small / coastal / shore based)	15	5
AUV Class #2 (medium / shelf)	15.5	5
AUV / Hybrid / longrange	14.5	2/3
AUV Class #3 (large / deep)	13.5	5
Bio-mimetic fish		1
Crawlers / rovers / benthic	13.5	3
Buoyancy Gliders deep	18.5	5
Buoyancy Gliders shallow	18.5	5
RPAs / UAVs / UAS	17	5
Mammals (OR IN OTHERS ?)	17	5
USV #1 (Short duration)	16	4/5
USV #2 (long endurance)	19.5	4/5
Buoyancy floats	20	5
Surface Drifters	19	5

Research

Operational

## Key

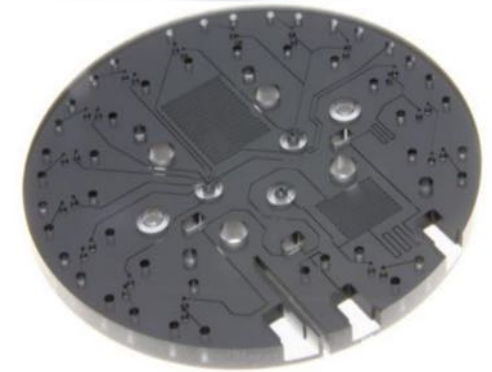
TRL	Technology Readiness Level
AUV	Autonomous Underwater Vehicle
RPV	Remotely Piloted Vehicle
UAV	Unmanned Ariel Vehicle
UAS	Unmanned Ariel Systems
USV	Unmanned Surface Vehicle



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Sensor/Platform	TRL
Lab on chip	
<i>nitrate</i>	3
<i>phosphate</i>	3
<i>silicate</i>	3
<i>ammonium</i>	2
<i>iron/manganese</i>	2
<i>conductivity, temperature, oxygen</i>	3-4
<i>nucleic acid sensor</i>	1-2
<i>synthetic immuno sensor - proteins, small organics, small molecules</i>	1
<i>cytometry</i>	1-2
<i>pH</i>	3
<i>Total Alkalinity / DIC</i>	2
Optode CO2	3
mass spectrometry	4
"Sniffer" methan, PAH/hydrocarbon, carbon dioxide	5
RAMAN	2
ESP/nucleic acid and protein sensor	4-5
Biotaguard (mussel valve opening and sponge)	4-5
acoustic recorders (hydrophone, passive, wide range)	5
automated flow cytometry (full size, in-line, data automation, different types)	5

# Sensors



## Lab on a chip

# Data Sharing

- Open Data != Free Data
- Discovering data – Metadata



- Beyond metadata – NoSQL Databases



- More to a dataset than a title, date and creator
- Beyond OGC – JSON JavaScript Object Notation, RESTful web services

# The Future

- Higher Resolutions
- Multi-parameter sensors (on a chip)
- Yet Faster Data
- Machine Learning – Targeted sampling
- Citizen Science – (e.g. beach morphology)
- Automated Model Optimisation / Validation



# The Future

- Armchair Oceanography?????



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