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Geological Survey of Ireland

GEOLOGICAL SURVEY OF IRELAND RESEARCH PROGRAMME
- Short Call 2015, Final Report -

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Organisation name	Dublin City University

Project Title	Mapping the spatial and temporal variations of water quality in Dublin Bay
Contract No.	2015-sc-077

INFOMAR
Tellus Understanding Underground
Marine Institute Foras na Mara

Project Report (*max 1500 words, excluding figures and headings*):

(i) . Objectives and scientific/engineering targets beyond the state of the art

- Develop a sampling rig for the in-situ monitoring of depth, conductivity, temperature colour and turbidity in Dublin Bay.
- Validate and ground-truth with a mobile sensing system (which can be towed by a boat) which will acquire data at a programmed sampling rate and relay the data with a GPS location stamp back to a base station on the boat.
- Further development of the sampling rig for deployment on both drifting and moored bouys that will allow data from the sensors to transmitted remotely at locations identified from boat transects
- Combine the data collected using these in-situ measurements with aerial thermal imaging and data in order to provide information on water column variables.

Project overview and outcomes:

Study Site: Dublin Bay

Dublin Bay is a C-shaped bay leading into the Irish Sea with a total volume estimated at 2.6 x 10^7 m^3 d^{-1} [2]. It is approximately 11 km long and 15 km wide with an average depth of less than 35 m [3]. The mouth of the bay spans between Howth Head to the north and Dalkey Island to the south. A prominent feature of the bay is North Bull Island which was formed as a result of the development of the port and is continuously growing [1]. The bedrock of the bay consists of lower carboniferous limestone. The River Liffey flows through Dublin City into the bay from the west. The Dodder and Tolka rivers flow into the Liffey before it reaches the bay. The total freshwater input to the bay is estimated to be 2.3 x 10^6 m^3 d^{-1} [2]. There are several large industrial sites in Dublin Bay including the Ringsend Waste Water Treatment plant and the Poolbeg Generating Station, a gas-fuelled power plant. An incinerator is under construction in Ringsend which will generate electricity from the combustion of municipal waste.

In-situ data acquisition

Objectives met in this section:

- Sampling Rig for monitoring depth, conductivity, temperature, colour and turbidity in Dublin Bay.
- Validate and ground-truth with a mobile sensing system (which can be towed by a boat) which will acquire data at a programmed sampling rate and relay the data with a GPS location stamp back to a base station on the boat.

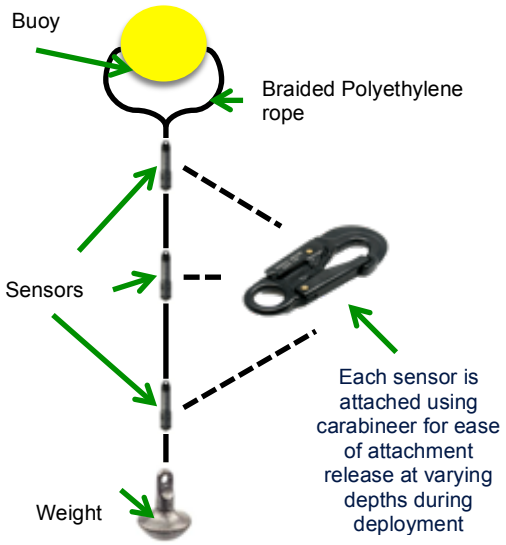
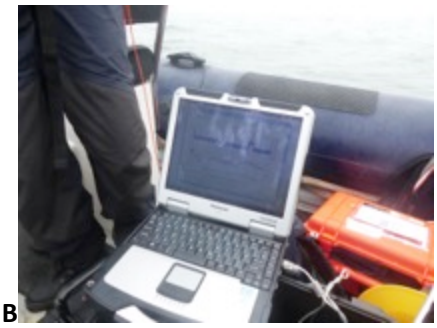


Figure 1 Schematic diagram of the sampling rig set up *setup of sampling rig developed for the deployment of CTD sensors in Dublin Bay*

Temperature, conductivity, and depth measurements were taken using three CTD-Divers (Van Essen Instruments) at approximately 0.5, 2, and 4 m depths. The sensors were deployed on a custom-made rig consisting of three detachable polyethylene rope lines attached to a surface buoy[4]. The rig was towed behind a rigid inflatable boat (RIB) travelling at a constant speed of approximately 2.5 knots. A sufficient distance between RIB and sampling rig was maintained to avoid interference from the wake created by the boat which would cause mixing of the water column thereby providing inaccurate measurements. The lines were weighted to ensure the rig was kept vertical whilst travelling through the water. A Baro Diver (Van Essen Instruments) was attached to the RIB (Figure 2C) to measure barometric pressure for compensation of the CTD data. Data from the CTD at 0.5 m was monitored in real time via cable connection to a Panasonic Toughbook on board running Diver Office software (SWS Technologies) to ensure the depth was kept at a constant. The UviLux (CDOM sensor) and turbidity sensor obtained from Chelsea Technologies were weighed. The boat position was continuously recorded using a handheld GPS (Garmin etrex 10 and etrex 20x).

A



B

C

Figure 2 A) The sampling rig being towed behind the boat during a transect of Dublin Bay. B) Toughbook aquiquiring data in real-time from the CTD diver on the surface C) A Baro Diver (Van Essen Instruments) was attached to the RIB (Figure 2C) to measure barometric pressure for compensation of the CTD data.

Once the sample rig was optimised and tested in the bay transects of the bay were carried out over a 3 day sampling campagin during each month June July and September. Over 380,000 in-situ data points were recorded during the project covering approximately 300km. During the September sampling campaign depth profiles were recored at locations idetified from data obtained during previous sampling campaigns.

A

B

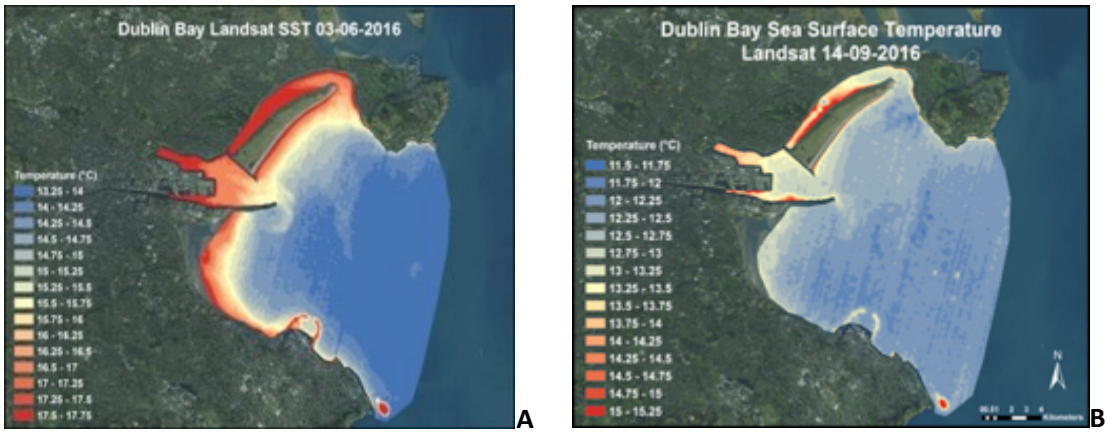
Figure 3 Map of transects carried out over the duration of the project, **A** Transect for June and July recording 147,000 data points, **B** Transect for September recording 238,150 data points the red dots indicate locations where point source sample were taken and depth profiles were recorded.

Results:

Objectives met in this section

- Further development of the sampling rig for deployment on both drifting and moored buoys that will allow data from the sensors to transmitted remotely at locations identified from boat transects
- Combine the data collected using these in-situ measurements with aerial thermal imaging and data in order to provide information on water column variables.

In situ measurements obtained during each transect of the bay were interpolated using the inverse distance weighting (IDW) method in ArcGIS to produce temperature and salinity maps. Sea surface temperature (SST) maps were produced using imagery obtained by the Thermal Infrared Sensor Instruments (TIRS) on the Landsat 8 satellite (USGS) (Figure 6). Digital numbers (DN) were converted to SST using ArcGIS software as described in the Landsat 8 Data Users Handbook see appendix 1. A total of 4 maps were derived



A B

Figure 4 A and B *Temperature map of Dublin Bay derived from Landsat 8 TIRS imagery*

Conductivity Temperature and Depth:

Preliminary results show the surface (0.5 m) temperature in Dublin Bay at the time of *in situ* sampling ranged between 14 and 15.25 ^{o}C. The perimeter of the bay appears to be warmer than the central area. Overall the temperature profile at the surface and 2 m depth appears to be similar. The 4 m depth measurements show a decrease in temperature range (13.8 to 14.5 ^{o}C) with less variation throughout the bay, although there is a slightly colder area in the centre of the bay similar to the measurements at shallower depths. Interestingly there appear to be locations of considerably warmer water to the north of Bull Island, south of Howth Head, and northwest of Dun Laoghaire Harbour. Further interpretation is necessary to determine the cause of these differences. Our results suggest that satellite imagery can be used to provide an overview of SST in a large marine bay, however the magnitude of some variations are not well represented such as for the areas of warmer water mentioned above. Salinity profiles indicate that water is generally fresher at the perimeter of the bay. Interestingly there appears to be substantial variation in salinity with depth. Values increased from 33.25 to 33.75‰ at 0.5 m to 37.05 to 37.5‰ at 4 m. It has been stated that river water floats as a coherent plume across the northern sector of Dublin Bay which would explain the lower salinity observed here Ref . However our results suggest that this less saline water is not limited to the northern sector. Maps were generated from data obatined during each

transect an example of the maps generated for transects completed in June are seen in Figure 5.

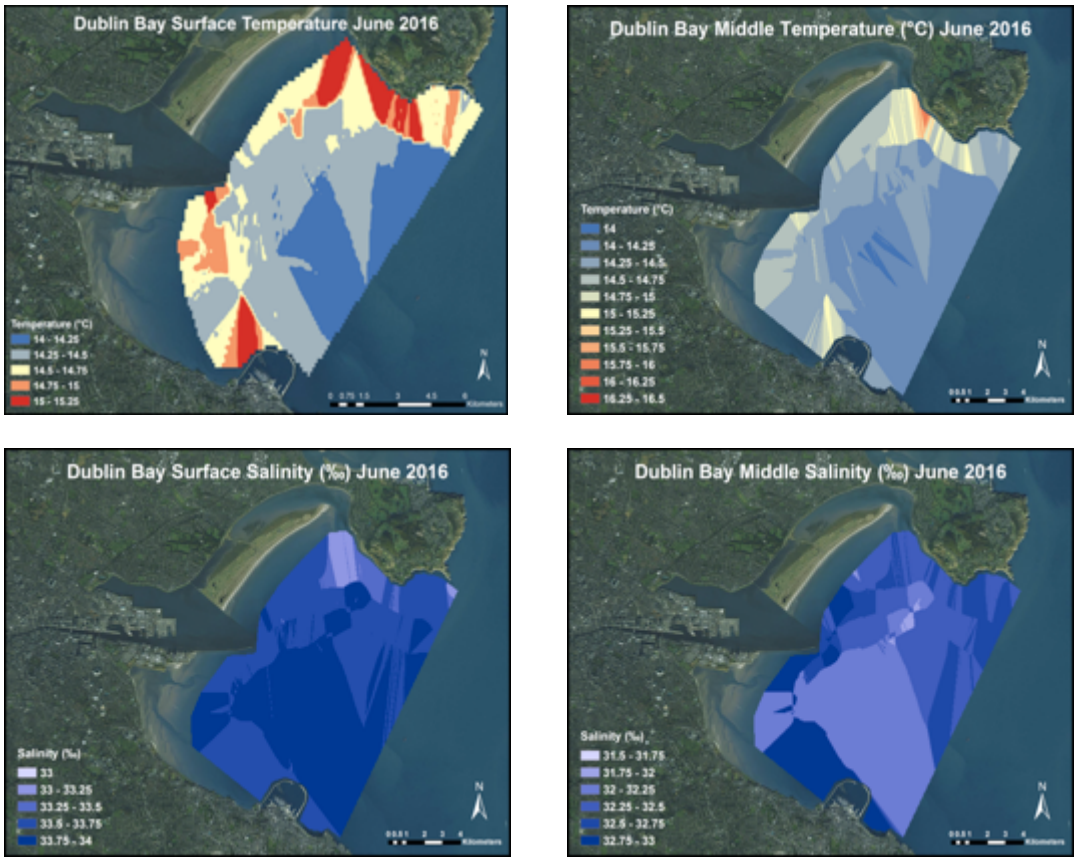


Figure 5 **A**. *Temperature map of Dublin Bay interpolated from in situ measurements at the surface.* **B**. *Temperature map of Dublin Bay interpolated from in situ measurements at 2m* **C**. *Salinity map of Dublin Bay interpolated from in situ measurements at the surface*. **D.** *Salinity map of Dublin Bay interpolated from in situ measurements at 2m.*

Turbidity and Colour

19,944 turbidity measurements were recorded at the surface on the 9th and 10th of June 2016. *In-situ* measurements were interpolated using the inverse distance weighting (IDW) method in ArcGIS to turbidity maps (See figure 6). In-situ turbidity measurements taken during the sampling camagin in July showed an increase in turbidity along the dredged channel coming from the Liffey, most likely due to the influx from the River Liffey. An incresase in temperature along the outflow was detected using thermal imaging camera during flyover carried out from NUI maynooth. This increase in temperature was not visible in data collected from temperature maps of Dublin Bay interpolated from in situ measurements at 0.5 m depth or temperature maps derived from Landsat 8 TIRS. This suggests that the higher temperature at the outflow is a result of the suspended materials as they can adsorb heat increasing the water temperature. The temp sensor contained in the sample rig towed behind the boat was set at 0.5m this may have been to low to detect the change in temperature caused by at the surface. To further investigate this point source samples were taken at the surface at each sampling point (Figure 3)

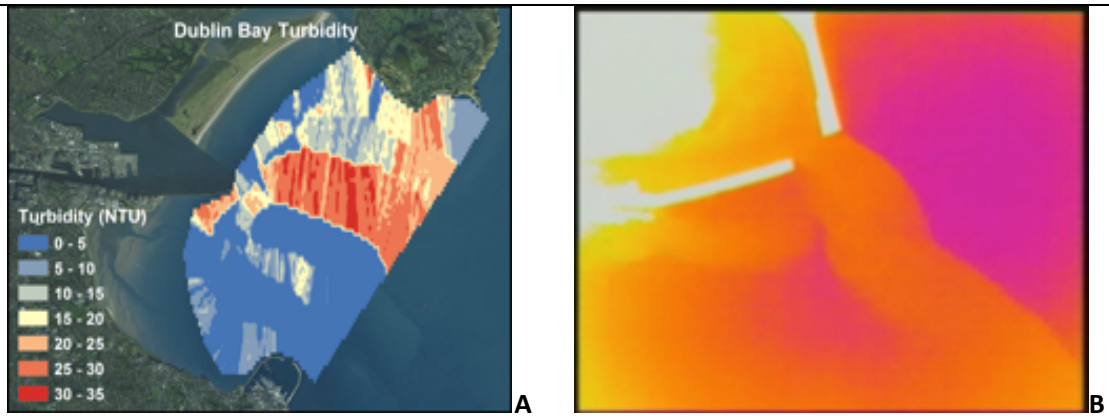


Figure 6. A. Surface turbidity map of Dublin Bay interoplated from in-situ data colleceted in June 2016. B. Thermal imagery of the outflow from the river liffey into Dublin Bay collected by NUIM during areial flyovers in July 2016.

Depth Profiles:

The sampling rig was further developed to allow for depth profiles to be recoreded at locations identified from data collected from transects completed in June, July and September. A total of 24 depth profiles were recoreded locations in Dublin bay and in the River Liffey. Water samples were also colleceted at the surface at each location and frozen for subsequent analysis. Examples of the salinity and temperature depth profiles recorded at stations 14 and 6 can be seen in Figure 7.

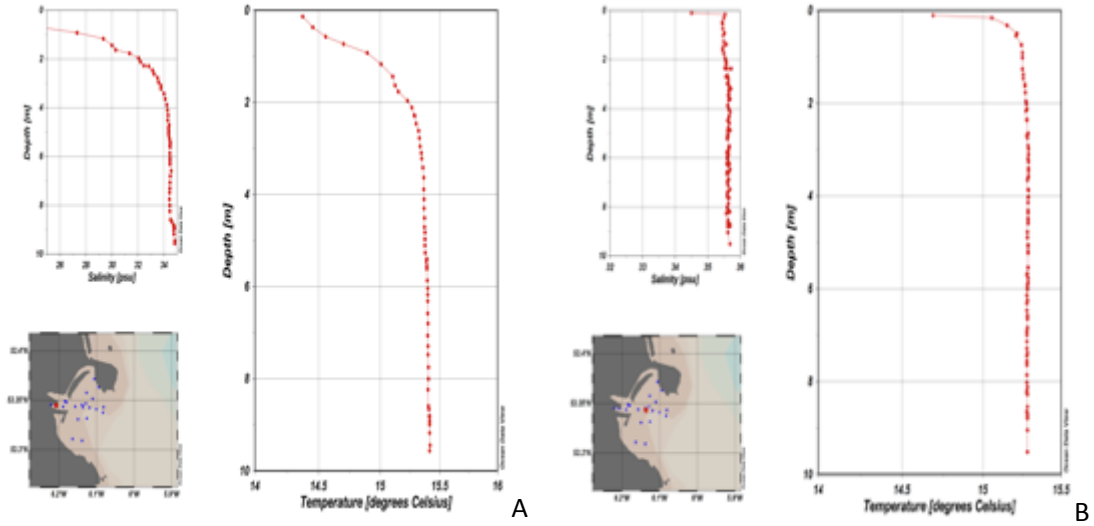


Figure 7. *Salinity and temperature depth profiles recordered at two stations (14, 6) identified from data obtained during boat transects of the bay*

(ii) Implementation (including reference to timelines, milestones, management)

- M1 Collection of colour, turbiity, conductivity, temperature and depth data from Dublin Bay using mobile sensing systems and boat based transects (month 4 -9).
- M2 Integration of the mobile sensing system onto moored bouys deployed at specific locations identified from data obtained using boat based transects (month 8 - 9).

  Due to marine traffic at locations of interest indentified from data obatained using boat transects it was not possible to integrate the sensors onto fixed moorings as an alternative the moblile sensing unit was adapted to record depth profiles at each location identified.

- M3 Integration of in-situ measurements with thermal imaging data and INFORMAR seabed mapping data. (Month 10)

(ii) Outputs (please use bullet points)

- Invited Keynote Lecture: INTEGRATING GEOSPATIAL REMOTE AND IN-SITU SENSING: OPPORTUNITIES AND CHALLENGES, Margaret McCaul, Jack Barland, Eoghan McNamara, Peter McCluskey, Conor Cahalane, Tim McCarthy, Dermot Diamond, presented at the international conference ISEH2016 and ISEG2016, NUI-Galway, August 15-17 2016.
- Poster Paper: MAPPING THE SPATIAL AND TEMPORAL VARIATIONS OF WATER QUALITY IN DUBLIN BAY, Sean Jordan, Margaret McCaul, Xavier Monteys, Conor Cahalane, Tim McCarthy, Dermot Diamond, presented at the international conference ISEH2016 and ISEG2016, NUI-Galway, August 15-17 2016.
- Tracking Dynamics of Freshwater and Marine Water Mixing using Satellite and Flyover Thermal Imaging combined with In-Situ Sensing, Margaret McCaul, Jack Barland, Eoghan McNamara, Peter McCluskey, Conor Cahalane, Tim McCarthy and Dermot Diamond, invited lecture presented at the conference 'Innovation in Environmental Monitoring', University of York, September 21, 2016.
- Mapping the spatial and temporal variations of water quality in Dublin Bay, Sean Jordan, Margaret McCaul, Xavier Monteys, Conor Cahalane, Brian Kelleher, Tim McCarthy, Dermot Diamond. Presented at the 2016 INFOMAR conference October 16th 2016.
- Research paper in preperation

Refences:

1. Brooks, P.R., Nairn, R., Harris, M., Jeffrey, D., Crowe, T.P., 2016. Dublin Port and Dublin Bay: Reconnecting with nature and people, *Regional Studies in Marine Science,* In Press
2. Wilson, J.G., Rybarczyck, H., Elkaim, B., 2007. A comparison of energy flow through the Dublin Bay and the Baie de Somme intertidal ecosystems and their network analysis, *Hydrobiologia*, 588 (1)
3. Murphy, B.T., O'Reilly, S.S, Monteys, X., Reid, B.F., Szpak, M.T., McCaul, M.V., Jordan, S.F., Allen, C.C.R., Kelleher, B.P., 2016. The occurrence of PAHs and faecal sterols in Dublin Bay and their influence on sedimentary microbial communities, *Marine Pollution Bulletin,* 106 (1-2), 215-224
4. McCaul, Margaret, et al. "Combining Remote Temperature Sensing with in-Situ Sensing to Track Marine/Freshwater Mixing Dynamics." *Sensors* 16.9 (2016): 1402.

Impact/value of the project (M*ax 500 words*):

The ability to track the dynamics of processes in natural water bodies on a global scale and at a resolution that enables highly localized behavior to be visualized is a ideal scenario for understanding how local events can influence the global environment. This study generated a large amount of new data comprising of in-situ temperature, depth and turbidity measurements at varying depths in Dublin Bay. In addition Landstat 8 satellite sea surface temperature measurements were studied for a period of 12 months when available. In-situ data was also compared to measurements obtained from thermal imaging collected from aerial flyovers conducted by NUIM. Sea surface temperature (SST) maps were produced using imagery obtained by the Thermal Infrared Sensor Instruments (TIRS) on the Landsat 8 satellite. In-situ surface and satellite data were compared and show good correlation. Suggesting that it may be possible to track the dynamics of freshwater-seawater mixing behavior in Dublin bay using temperature, either by in-situ temperature measurements or via satellite remote imaging. More extensive studies should be invoked to validate these conclusions, and (if positive) identify the boundaries of the correlations, and the relative impact of various influencing factors.

Appendix 1 – Publications & Presentations:

- Invited Keynote Lecture: INTEGRATING GEOSPATIAL REMOTE AND IN-SITU SENSING: OPPORTUNITIES AND CHALLENGES, Margaret McCaul, Jack Barland, Eoghan McNamara, Peter McCluskey, Conor Cahalane, Tim McCarthy, Dermot Diamond, presented at the international conference ISEH2016 and ISEG2016, NUI-Galway, August 15-17 2016.

- Poster Paper: MAPPING THE SPATIAL AND TEMPORAL VARIATIONS OF WATER QUALITY IN

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Appendix 2 – Any additional information not included above: