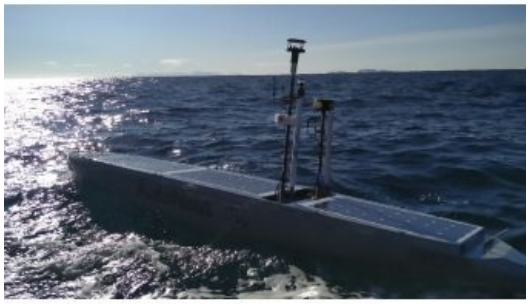
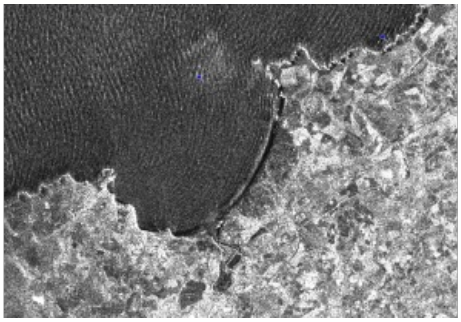
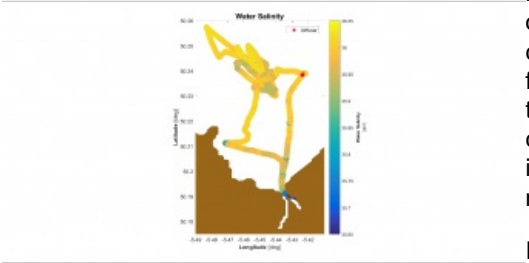
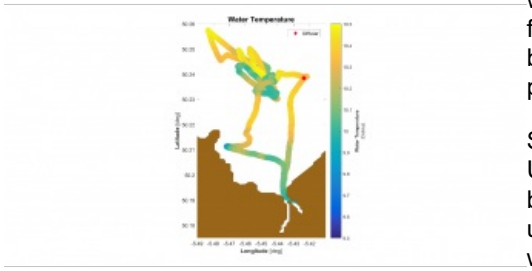
AUTONOMOUS SURVEYING OF SHALLOW COASTAL WATERS FOR CLEAN SEAS AND SHORELINES

Coastal Monitoring of Water Quality









The wave-propelled AutoNaut unmanned surface vessel (USV) completed a short trial off the south-west coast of England to monitor the water quality by a sewage outfall. AutoNaut demonstrated its ability to reliably operate in shallow waters whilst also recording and transmitting data. A suite of sensors aboard the USV worked in conjunction with satellite data from synthetic aperture radar (SAR). Analysis indicated that the seawater close to the outflow was not negatively affected. The combination of technologies is pioneering for the application and the trial highlights the potential of this innovative approach to conduct long-term marine monitoring – including the reduction of costs and risks relative to conventional methods.

In the trial, commissioned by a UK water utility, sensors measuring water quality were installed in a 5-metre AutoNaut USV. The mission aims were to detect the plume from a coastal sewage outfall and establish its characteristics. Contemporaneous satellite-based synthetic aperture radar (SAR) data was analysed to establish whether the same plume could be detected from space.

Surveying in rugged coastal waters presents additional challenges for any boat. For a USV, completion of a survey so close to land requires both the autonomous technology to be 100% reliable and the craft itself to have proven sea-worthiness. The AutoNaut USV uses patented Wave Foil Technology to propel itself forward solely by the motion of the waves. It maintains an average of 3 knots and can operate in all sea conditions - with an auxiliary propeller in case of flat-calm conditions. The craft is highly manoeuvrable and can confidently keep station within a 50-metre radius. Additionally, the boat has very little draft, having no sub-sea tethered mechanism, and is therefore able to work safely in shallow waters. Solar panels and a battery bank power a suite of sensors for the project objectives. This use of renewable energy enables very long-term missions to be completed – with no requirement for fuel. Autonomy at sea, albeit with oversight from onshore operators, also removes the safety risks of personnel working offshore.

Survey Method and Equipment

The mission was completed over a 24-hour period in January 2017. The AutoNaut track passed over the diffuser and maintained a search pattern approximately 0.25 nautical miles from the diffuser, 2 miles out from land. The AutoNaut was fitted with a YSI EX02 Sonde unit with sensor nodes for water chemistry, including: Conductivity, Temperature and pH. Additionally, a Gill Windsonic weather station was fitted on the mast to measure wind speed and direction.

Operating close inshore presented challenges. The site had limited sea room and the USV was always in close proximity to the rocky shoreline, often as near as 2 miles from land. Strong local tides and the UK winter weather were watched carefully, as were the potential hazards of lobster pots and flotsam. In line with guidelines set out by the Maritime Coastguard Agency, the presence of a support boat was

deemed to be a necessary precaution. For the duration of the trial, the support boat was at sea and on standby for safety assurance but did not otherwise take a direct role in the autonomous operation

Local communication wireless links enabled the on-site team to issue control commands whilst in line of sight. However, satellite link via Iridium means remote operations can be overseen from anywhere in the world. In this instance, from AutoNaut's headquarters in Chichester, UK.

The simplicity of the AutoNaut design allowed it to be transported in the back of a van to the launch site. The team assembled the USV on the quayside in a matter of hours and, after procedural checks, it was put to sea to begin surveying. The AutoNaut was deployed manually by a small team from a local slipway.

The intention to complete the AutoNaut mission contemporaneously with the availability of the satellite SAR data meant a narrow window of opportunity. Two days in January were the only viable trial days when tide times allowed entry/exit from the harbour base during the restricted daylight hours. In order to deliver a comprehensive dataset over a tidal cycle, a 24-hour continuous mission was completed with the AutoNaut over dates which included the time slot for the Sentinel 1B satellite overpass.

Weather and sea conditions were worse than forecast and a patrol line was set up in a safe operating area to the south and west of the diffuser for the duration of the mission from where the outflow plume from the diffuser could be monitored through approximately 50% of the tidal cycle.

Satellite-based Synthetic Apperture Radar (SAR) Data

The SAR imagery captured clearly shows the Atlantic swell and the white water around the rocks and Island on the vertical polarisation image, but gives no definitive indication of any fresh water plume from or around the diffuser. It has been proven that such images are able to clearly show evidence of oil or sewage effluent on the water surface in low sea states due to the smoothing effect of the contamination on the sea/wave surface. It has not been demonstrated that SAR imagery can define a fresh (i.e. clean) water plume as the small change in water density is unlikely to cause the same effect.

However, salinity and temperature will be particularly relevant markers for a fresh water plume on the surface as long as the mixing effect of the wave/swell action is not vigorous enough to dilute the fresh water through the water column. Given the prevailing weather conditions, it would be unlikely that any normal fresh water flow from the diffuser would remain unmixed at the surface for a sensor mounted in the AutoNaut to be able to detect it.

Autonaut Data

As figure 4 illustrates, the salinity of the water throughout the mission remained stable, and the temperature only fluctuated by 0.5°C (Figure 5). There was no change to the readings over the 2 tidal cycles of the mission; the tidal flow in the bay changes direction from ENE to WSW approximately 90 minutes after the times of HW and LW. Any change to the data would be visible when the ebb tide was flowing WSW but there is no change to either the salinity during those periods and the small changes to the water temperature do not provide any direct evidence of the presence of fresh water during those periods.

Conclusions

During this particular survey, no plume was detected by either the USV sensors or by the satellite SAR imagery. It is not known what volume of outfall discharge there was to detect at this time but it is thought that mixing in the turbulent sea conditions prevailing during the demonstration will have obliterated outfall traces. The trial successfully demonstrated that data on sewage outfall plumes can be gathered contemporaneously from space-based SAR imagery and the AutoNaut USV at sea. The combination enables SAR satellite imagery to cover a potential pollution incident with persistent ground-truthing of such an incident by the AutoNaut USV. Such flexibility makes it possible to deliver an accurate definition of the extent of a marine pollution incident. Satellite coverage is extending and the availability of SAR imagery is increasing. Similarly, USV technology, such as AutoNaut, is constantly maturing and proving its capabilities. For the future, distinct potential is emerging for a space-based autonomous system to provide early warning and prompt real-time response – and significantly reduce the impact of marine pollution.

Future Projects

Lessons from these coastal water deployments are about to be brought together in a highly ambitious mission in south east Asia. Two new 5-metre AutoNauts are being prepared to monitor pollution from oil spills where a busy shipping lane passes close to vulnerable mangrove swamps and valuable tourist resorts. AutoNaut will ground-truth space-based SAR observations enabling the local authorities to both tackle pollution and eventually to prosecute offending ships.

Other coastal monitoring roles for AutoNaut are being developed with partners in the United Arab Emirates where the 10m deep coastal water extends 20 kilometres from the coast. With some 11 artificial islands being built as oil and gas productions platforms, and new nuclear facilities coming on stream, there is a significant need to automate the long-term monitoring of this shallow-water habitat, a task for which AutoNaut is uniquely suited.