Catchment to coast information integration: a South-east Queensland example with national application

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Abstract

Management across the catchment-coast-ocean continuum remains one of the greatest Natural Resource Management (NRM) challenges still to be addressed in Australia. To do so requires an underpinning Coastal Knowledge platform that integrates observational (e.g. monitoring and remote sensing) data with modeling of catchment, estuarine and coastal processes in a way that allows management agencies to comprehensively assess and report the status and outlook for these coastal assets, and the success, or otherwise, of current or proposed management interventions. The SEQuITOR (South East Queensland Integrated Terrestrial to Oceans Research) project is a first step in this direction. SEQuITOR harnesses investments and innovations in observation networks (e.g. TERN, IMOS, ANDS, State agencies, CSIRO) and integrated catchment and receiving environment modelling to develop data delivery, assimilation and visualisation infrastructure that will allow researchers and managers to better understand the strong, but often highly episodic (e.g. floods) connection between activities in the catchment and the effects on downstream coastal and marine aquatic water quality and ecosystem health. The service-based approach utilised in SEQuITOR has broader national application and is directly contributing to other regional and national initiatives such as the eReefs and the Terrestrial Ecosystem Research Network (TERN) Coastal Facility. Collectively, these systems are reducing the cost of entry for data custodians to contribute to the national information infrastructure. For coastal managers and researchers, this means easier and more direct access to relevant research, data and information products from a wide variety of sources.

Introduction

The concentration of populations globally in coastal regions and the accompanying resource usage pressures finds coastal regions around the world facing significant issues (Barker 2006, Gurran, Blakely et al. 2007). Australia's vast and diverse coastal systems are vital to our population, economy and national wellbeing. Already, 85 per cent of Australians live in our major state capital cities and regional centres along the coastal fringe (Commonwealth of Australia 2009). As our population grows over the next few decades, the demand for urban space, industrial development sites and services in these regions will grow significantly (EPA (Environmental Protection Agency) 2008, Commonwealth of Australia 2009). Much of Australia's industrial, commercial and tourism infrastructure is located along the coast, as are our vital transport hubs. In south-east Queensland pressures imposed by our increasing footprint on coastal systems, combined with the projected impacts of climate change, present huge challenges for local, state and federal governments as they seek to adapt to and plan for future growth while maintaining the health of our marine, estuarine and terrestrial ecosystems (Alam, Rolfe et al. 2008).

Like many other parts of coastal Australia, South East Queensland (SEQ) is a region of high biodiversity experiencing significant pressure from rapid human population growth in response to industrial and residential development, shifts in urban and rural land use and, more recently, significant climate variability, prolonged drought and dramatic floods. In the next 20 years, the population of SEQ is predicted to grow from 2.8 to 4.4 million people and much of this growth will occur in peri-urban areas, notably in the catchments between greater Brisbane and the Gold Coast and Sunshine Coast.

The development, transformation of landuse and exploitation of resources associated with this population growth will intensify the pressure on catchment, aquatic and coastal environments. This is expected to lead to significant habitat fragmentation, water quality issues, biodiversity loss and a reduction of economic benefits and amenity values. The inherent vulnerability of these ecosystems will be compounded by the effects of climate change in the region resulting in warmer land and water temperatures, changing rainfall and hydrologic patterns, increased variability and severity of extreme events, and changing biogeochemical cycling (Scheltinga, Counihan et al. 2004).

Over the last decade, there has been significant investment in monitoring and modelling activities in the catchment to coast continuum. This has resulted in valuable collections of data, although there has been limited integration of this information. Innovation is required to capitalise on our ability to observe and model catchment, estuarine and coastal processes in a way that allows management agencies to comprehensively assess and report the status and outlook for these assets, and the success— or otherwise—of current or proposed management interventions.

A challenge facing the ecosystem research community is determining how to link results and observations across different geographical scales; from site based species data and observations, to regional and then continental scale levels of integration, whilst recognising the interregional dependencies and connectivity (Bunn, Abal et al. 2010). This linkage is required to facilitate management at the scale of the landscape. Traditional approaches to monitoring and managing ecosystems have typically involved small-field experimentation, or less often, catchment based approaches (Abal, Dennison et al. 2005). The increased presence of regional catchment management bodies in Australia has created demand for development of whole-of-catchment management strategies for the improvement of water quality, and thus continued delivery of high quality ecosystems services.

The concept of a “super-site” links observations at specific sites (such as flux, vegetation plots, etc) with transects to provide the scaling from point to region. With co-investment from the Queensland Government, TERN has established a peri-urban super site in South-east Queensland, which is intended to serve as an exemplar for more extensive investments in the future. The goals of this super-site include integrating existing data and deploying infrastructure to both complement and automate acquisition of key data by examining carbon, nitrogen, water and energy balances and biodiversity monitoring in contrasting native and managed ecosystems typical of the landscape mosaic within peri-urban ecosystems. The integrated data has been published via a suite of integrated web services known as the South-East Queensland Integrated Terrestrial to Ocean Research network (SEQuITOR).

The SEQuITOR data services will assist Coastal managers and researchers to synthesise and report on large amounts of information without having to extract and manually process data. The primary interface for the network a flexible mapping and visualisation platform which will allow them to:

- access key datasets which are of use for coastal management
- combine, analyse and visualise datasets
- extract visual products (e.g. maps, graphs) and datasets in formats which are usable in management products (i.e. publication ready, discoverable information about the who owns the datasets, where the data has come from and what is in the data
- map the location of monitoring sites
- combine different types of datasets in the same map, e.g. monitoring, modelling, real-time and supporting layers.

The availability and accessibility of this data will allow researchers to better understand the impact of potential threats to coastal ecosystems, including flood, storm, sediment movement, diffuse pollution and the significance of any environment change(s). This will subsequently result in better holistic understandings of the processes and drivers of change in coastal environments. Better integration of datasets will also increase reuse and consistency of use of datasets by streamlining the process by which researchers acquire and use data. The SEQuITOR development team will be working closely with some key research and management users in South East Queensland to test and evaluate how well the newly-deployed system meets these needs, and to improve it in response to their feedback.

Methods

The primary users of SEQuITOR are expected to be coastal managers and researchers, although SEQuITOR will also deliver tools and information to a wider audience which is becoming increasingly data-aware.

SEQuITOR has adopted a standards-based approach, utilising Open Geospatial Consortium (OGC)(www.opengeospatial.org), standards and open data licensing (www.creativecommons.org.au) wherever possible. SEQuITOR has implemented a range of systems to support OGC standards and service based delivery of datasets. Software implementations include open source components including PostgreSQL (www.postgresql.org), PostGIS (www.postgis.net), GeoServer (www.geoserver.org), GeoNetwork (www.geonetwork-opensource.org) and THREDDS Data server (www.unidata.ucar.edu/software/thredds/current/tds/) as well as custom built components such as CSIRO's Sensor Message Gateway and SensorCloud and extensions to the Australian Ocean Data Network's Data Portal (www.aodn.org.au). In addition, a series of server-side development and monitoring tools have been implemented to ensure efficient development procedures and optimal response to server and service issues.

The PostgreSQL, PostGIS and GeoServer components are responsible for storing and delivering spatial data components such as catchment boundaries and other supporting layers. Core metadata information is stored in PostgreSQL and delivered through GeoNetwork.

CSIRO's SensorCloud and Sensor Message Gateway systems add the capability to deliver complex time-series monitoring data such as water quality monitoring data. Time-series data of varying temporal intensities (ie. both routine monthly monitoring and 5-minute continuous sampling) have been incorporated into this system. The Sensor Message Gateway component allows multiple disparate datasets to be established as data sources. These data sources are highly configurable and easily replicated. The data sources are then routinely ingested into a 'NoSQL' database (MongoDB) by the Sensor Message Gateway. A NoSQL database is a highly scalable database which is well suited to handling very large quantities of data without having the overheads of relational data structures. The SensorCloud component then provides a REST (Representational State Transfer) Application Programming Interface (API) on top of the database store. This system can deliver very large quantities of data in web-time (i.e. suitable for web applications), something that has previously been very difficult to do using traditional database structures.

The THREDDS Data Server, including ncWMS manages the delivery of complex three-dimensional model datasets. THREDDS allows for data to be aggregated, sliced and extracted along various axes (e.g. time, space, depth, multiple parameters), allowing data cubes to be visualised along with other datasets.

The combination of methods adopted allow end users to integrate, overlay, visualise and extract datasets using the SEQuITOR portal and have been developed to achieve easy access to datasets that have previously only been accessible as separate products. This approach aims also to achieve more integration of data services with desktop tools, such as the direct integration of time-series data into modelling workflows or statistical tools.

Additionally, complex, three-dimensional results from a long-running hydrodynamic model of Moreton Bay are available, providing very high spatial and temporal intensity, at multiple depths. Parameters include, seabed depth, surface elevation (tidal surge), salinity, water temperature and water velocity. Traditionally, these results are delivered as very large files and in formats which are difficult for many users to understand. This can make modelling data difficult to analyse using standard tools. By using standards based and open source tools, these complex datasets are made available through SEQuITOR in a variety of formats and are integrated into the SEQuITOR portal. These data cubes can be aggregated and sliced in various ways (users can select specific times, parameters, depths, etc.) and users can visualise model data alongside other spatial data or time-series data, see Figure 3).

Results

The development of SEQuITOR has resulted in:

1. Web-based tool for graphical exploration and visualisation of datasets with a time slider that shows changes in key features along the catchment and into Moreton Bay. (http://www.seqitor.org.au)
2. Service based delivery of complex datasets including time-series data of varying temporal frequencies and 3-dimensional model outputs.
3. Integrated publicly accessible datasets that can be used for a variety of follow-on analyses and research projects

More details can be found at http://blog.seqitor.org.au/2013/01/why-is-seqitor-needed-and-how-do-we.html

SEQuITOR successfully provides access to a range of datasets which vary in spatial and temporal extent. Users can easily combine spatial elements from monitoring data and modelling data with other spatial layers and interact with them through time (see **Error! Reference source not found.** and **Error! Reference source not found.**). Alternatively, users can add “pseudo sites” from the model layer to the time-series chart and graphing this modelled point alongside high frequency or monthly monitoring datasets. This provides a powerful mechanism for users to interact with datasets online when they would normally need to acquire and process these datasets individually.

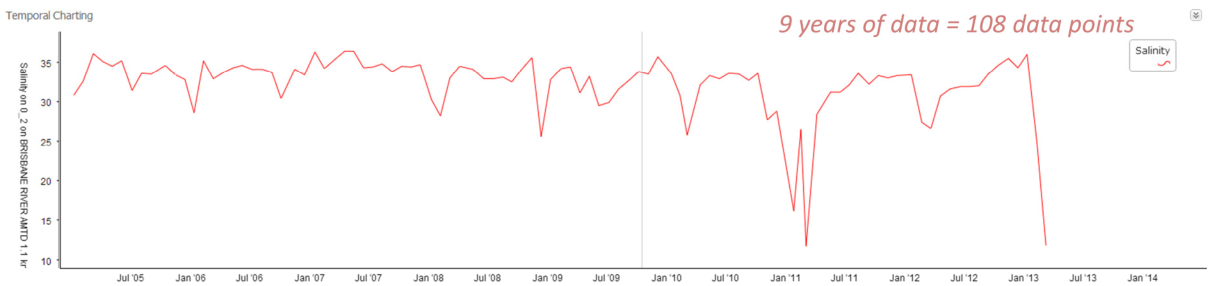

Figure 1: Visualisation of monthly water quality monitoring data over 9 years (data provided through the SensorCloud system)

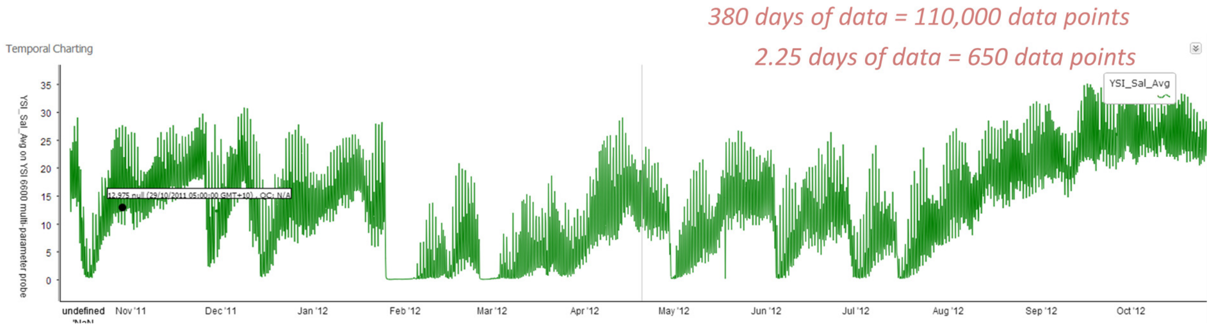

Figure 2: Visualisation of high frequency (5 minute) water quality monitoring data over approximately one year (data provided through the SensorCloud system)

More importantly, SEQuITOR provides a framework for future integration of multiple datasets from a diversity of providers. The collection of tools and services mean that any type of data, no matter how spatially or temporally complex, can be incorporated, either by hosting data on SEQuITOR services, or by linking to existing services from other data providers.

This can then result in much greater use of datasets, better research products and greatly reduced reliance on fragile data access methods. SEQuITOR will allow coastal mangers to shortcut this process by allowing them to produce flexible and customisable graphical products in the same system through which they can download data and the same system which their modelling or statistical teams can also make use of (see Figure 3).

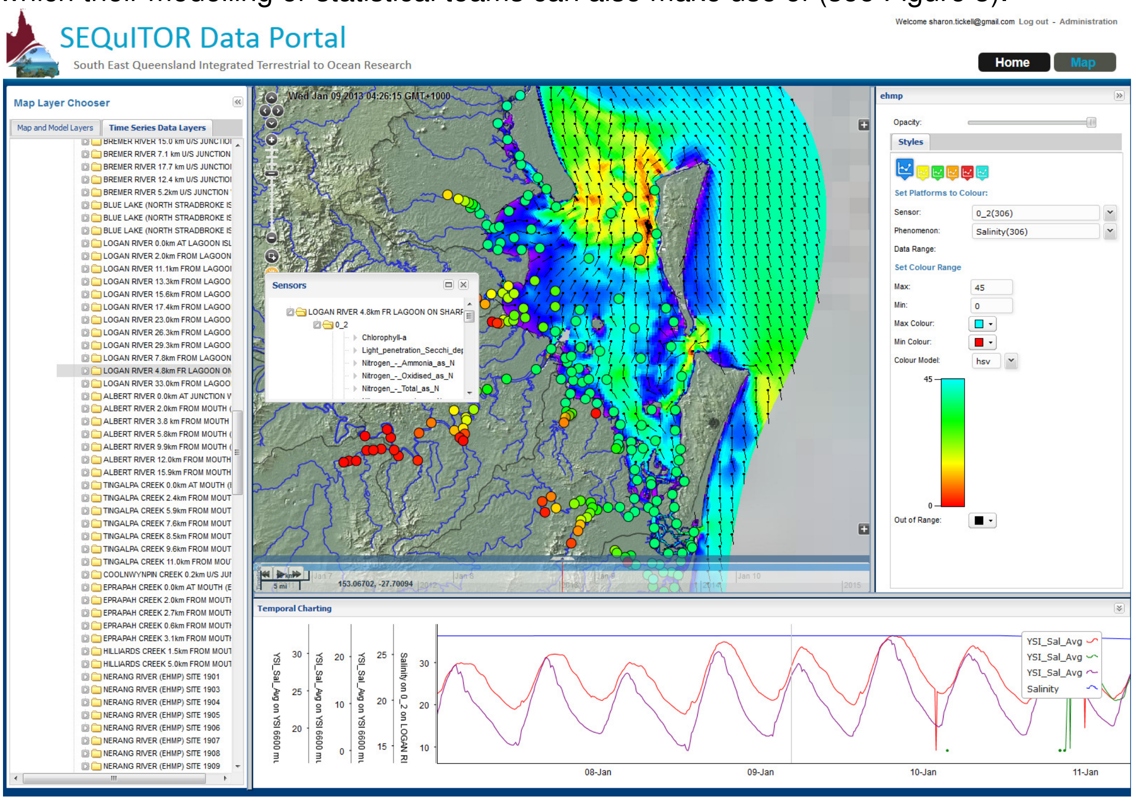

Figure 3: Spatial and temporal view of multiple time series monitoring datasets including monthly monitoring data and high frequency (5 minute) monitoring data (all data provided through the SensorCloud system with background layers coming from PostgreSQL, PostGIS and GeoServer)

The success of SEQuITOR will be dependent on and measured by engaging with key users in both the research and management domains. We will be working with users within these domains - both at the senior expert level and at the data handling and processing level to ensure that we can deliver tools and information to the people that help make the decisions as well as the people who produce content to provide to the decision makers. Simplicity is the key to user uptake and the interface provided by SEQuITOR provides for intuitive use,

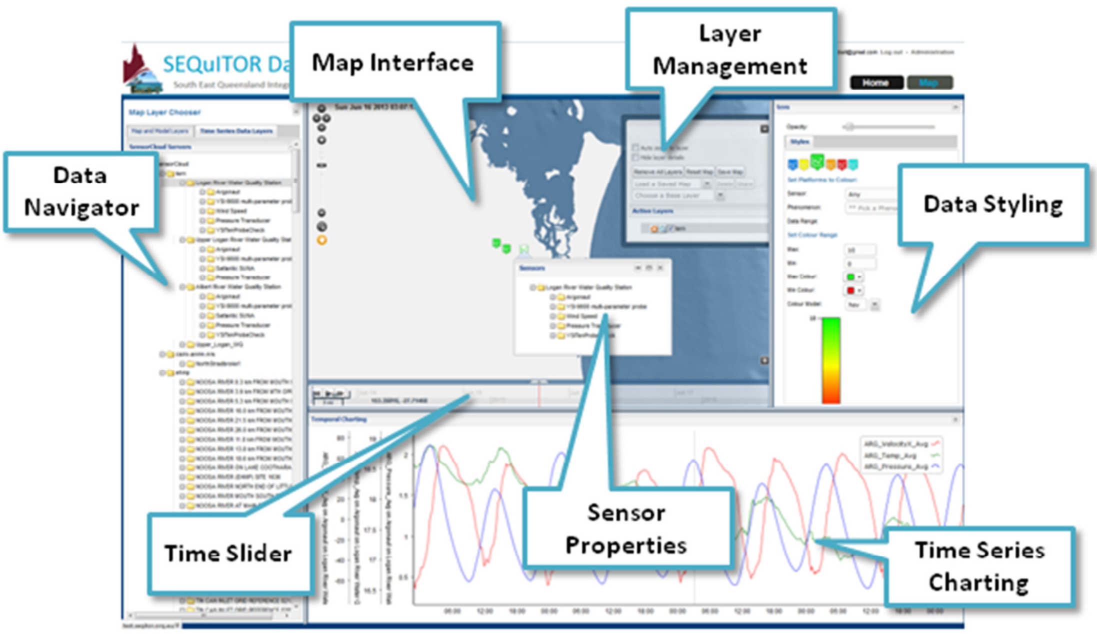

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Figure 4.

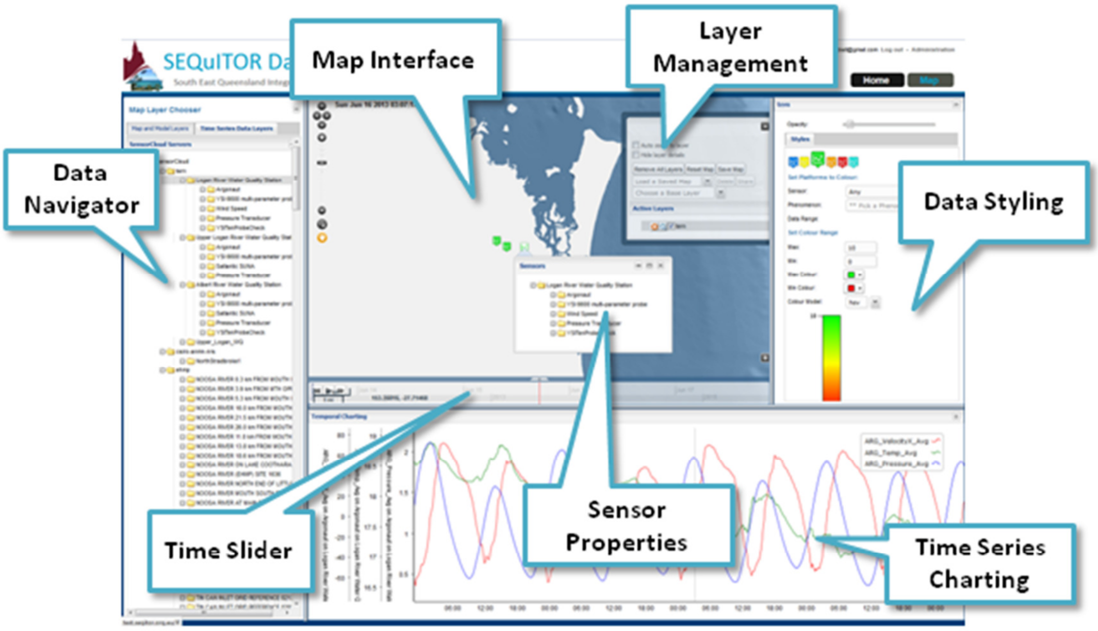

Figure 4: Overview of the SEQuITOR portal

Discussion

The importance of readily available information that would allow NRM managers to devise, apply and assess effectiveness of management actions to guard coastal assets has been recognised for decades dating back to the Commonwealth Resource Assessment Commission (RAC) Coastal Zone Inquiry (Australia Resource Assessment Commission 1993, Flaherty and Sampson 2005). Increasingly anticipatory decisions are also required, particularly as we move more towards coastal emergency preparedness and response measures.

Access to raw data can be a slow and manual process which is usually achieved via emails, direct discussions or possibly website downloads. In the science and research community, there are also frequent examples of "web scraping" where end users develop scripts which extract data from standard websites. This requires highly custom code and is very fragile due to the regularity of websites being updated or changed.

SEQuITOR provides a framework for the integration and dissemination of a large range of data types. By implementing systems which can handle complex spatial and temporal datasets, end users can start to access information in a much more consistent way.
This is an important step towards improving evidence-based decision making. The challenge still remains to demonstrate to managers and policy makers that data can be used effectively in their day-to-day activities and this may require additional components to be added to these sorts of portals, but SEQuITOR provides a platform for this discussion to develop.

Conclusions/Take Home Messages

South East Queensland Integrated Terrestrial to Ocean Research delivers multiple types of datasets in ways which users can interact with easily and quickly:

- view monitoring data, model data, spatial data
- minimise the level of manipulation required to combine datasets
- allows end users to extract data from multiple sources

SEQuITOR is an approach to show the power of combining disparate datasets and is a first step towards demonstrating the benefits of data sharing. In order to achieve this, government and research organisations need to continue to commit to open licensing and sharing of information. The national research infrastructure provided through NCRIS and EIF and activities such as TERN, ANDS and others provide the opportunities for government and research agencies to successfully sharing information, although many organisations do not understand how these activities fit together. Communication tools such as SEQuITOR can help solve this.

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