ICON.NL: COASTLINE OBSERVATORY TO EXAMINE COASTAL DYNAMICS IN RESPONSE TO NATURAL FORCING AND HUMAN INTERVENTIONS

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Abstract: In the light of challenges raised by a changing climate and increasing population pressure in coastal regions, it has become clear that theoretical models and scattered experiments do not provide the data we urgently need to understand coastal conditions and processes. We propose a Dutch coastline observatory named ICON.NL, based at the Delfland Coast with core observations focused on the internationally well-known Sand Engine experiment, as part of an International Coastline Observatories Network (ICON). ICON.NL will cover the physics and ecology from deep water to the dunes. Data will be collected continuously by novel remote sensing and in-situ sensors, coupled to numerical models to yield unsurpassed long-term coastline measurements. The combination of the unique site and ambitious monitoring design enables new avenues in coastal science and a leap in interdisciplinary research.

Introduction

Climate change and rising population pressure are driving increasing risk for coastal domains worldwide, and especially for low-lying deltas (Hinkel et al., 2015, Neumann et al., 2015). At the same time, the importance of coasts for recreation, fresh drinking water, economy and human habitat is steadily increasing (e.g. Temmerman et al., 2013), resulting in additional pressures to the coast. Yet, our knowledge base to manage or mitigate these – sometimes conflicting – challenges lags behind.

Modern-day sustainable coastal design concepts such as Building with Nature (De Vriend et al., 2015) or Engineering with Nature (Bridges et al., 2014) demand fundamental insight in the complex interplay of hydrodynamic, morphological and ecological processes. In the past, improved understanding was mostly derived from laboratory experiments or dedicated theoretical research on isolated processes. These experiments have contributed importantly to the development of quantitative insight in nearshore waves, currents and sediment transport, as well process-based models to described these phenomena.

By the 1990s, high-resolution field observations made coastal scientists recognize the importance of feedbacks, emergent behaviour and nonlinear system dynamics in the nearshore coastal zone (e.g. Holman et al., 1993). It was realized that isolated process studies in the lab could yield only limited improvement in predictability if feedbacks and emergent behaviour are part of the natural system. At the same time labs are usually incompatible with many interdisciplinary studies (particularly biotic components), while mimicking coastal behaviour in laboratory setting is often met with scale effects. As a consequence, laboratory data cannot be used to represent the range of conditions and potentially their sequencing that characterize the natural forcing and eco-morphological evolution of beaches. In response to this, coastal scientists embraced field experimentation and observation. While productive, these programs have been expensive, logistically challenging, and mostly of limited duration. Thus, there is a global need to facilitate and simplify study of the natural domain.

International Coastline Observatories Network (ICON)

To cater for the new paradigms in coastal science, engineering and management, nearshore researchers are in urgent need of world-class, natural coastline observatories to provide continuous, long-term and high-resolution monitoring of coastal processes. For that reason, international lead scientists have initiated the establishment of an International Coastline Observatories Network (ICON). Using the best sensors and techniques available, each observatory provides the core measurement capabilities that can themselves be the focus of research, but also provide the compassing synoptic data needed to accommodate focused, high-resolution field experiments by international research consortia.

Each observatory should connect the coastal community across multiple disciplines and perform concerted data collection instead of mono-disciplinary, scattered experiments. By adding observatories to the network on the basis of complementary site characteristics and environmental conditions, data sampled from the network sites will allow for holistic investigation of coastal processes, while covering a broad range of spatiotemporal scales. To promote broad dissemination and use in science and society, each observatory should be built on the basis of open-access protocols, with no barriers for data exchange and collaboration.

Following these principles of focused monitoring efforts, we are working on the establishment of an observatory named ICON.NL, the Dutch node of the international ICON network. The objective of ICON.NL is to establish a truly multidisciplinary data corpus, which will inspire and enable internationally outstanding coastal research, fundamental as well as applied, by the Dutch coastal science community and their international partners. To that end, ICON.NL will fuse high-resolution remote sensing observations, in-situ measurements and model-derived data to produce time-varying, dynamically-consistent maps of the important nearshore geophysical variables. ICON.NL output will be provided to the world in near-real-time using accepted, open-access dissemination protocols.

The Dutch node: ICON.NL

ICON.NL will be based at the Delfland Coast with core observations focused on the internationally well-known Sand Engine experiment (De Schipper et al, 2016), a man-made sandy peninsula built to ensure coastal safety as well to promote nature development, science and recreation. The observatory will also encompass the adjacent, more representative coastal environment fronting the town of Kijkduin, just to the north. The facility boundaries, including the Sand Engine, are shown in Figure 1. In the cross-shore, our goal is to sample from the shoreface (~10 m depth) through the dunes, sampling 24 hours per day on an hourly time scale, for initially five years at least.

Fig. 1. Aerial photo of the proposed ICON.NL location. The Sand Engine is the region of anomalously wide beach while the adjacent Kijkduin beach segment is the straight beach to the north. The tall tower visible in the centre of the Sand Engine is the location of several of the proposed remote sensing instruments. Note the large spatial variation in waves and beaches in the location of interest.

To have scientific value, ICON.NL will deliver a one-of-a-kind data corpus featuring direct measures of the core environmental variables including waves, currents, bathymetry, terrestrial sediment transport, beach topography and ecology, as well as mapped variables created by competent numerical models coupled to observations using accepted data assimilation principles. The facility will operate not in short-experiment modes but continually, thereby sampling the full range of storm-to-calm conditions and availing ourselves to all opportunities provided by natural coastal dynamics. Against these ambitious needs, we must balance the logistical and financial costs of extended sampling.

Success will require automated, real-time or near real-time data collection and processing as well as predictable dissemination such as would be expected in a mature traditional laboratory setting. Data collection must be sufficient to allow robust testing of core physics, usually represented by numerical models that can now be tested in operational scenarios, as well as providing the synoptic data streams needed to support more focused research programs that will be carried out on site by individual scientists or research team over shorter durations.

ICON.NL will allow field experimentation to advance our understanding in fundamental science topics such as unsteady currents and circulation, sediment transport near the beach, emergent morphological patterns, wave breaking/turbulence and storm/recovery cycles. It will facilitate research on dune evolution (including aeolian sediment transport and its interaction with vegetation), marine benthic processes and ground water dynamics. It will also accommodate interdisciplinary work that crosses the sea-land interface, which has always been difficult or impossible to perform in traditional labs. And last but not least, the data obtained will enable the development and validation of numerical models, and serve as a test bed for novel in-situ sensors and remote sensing technologies.

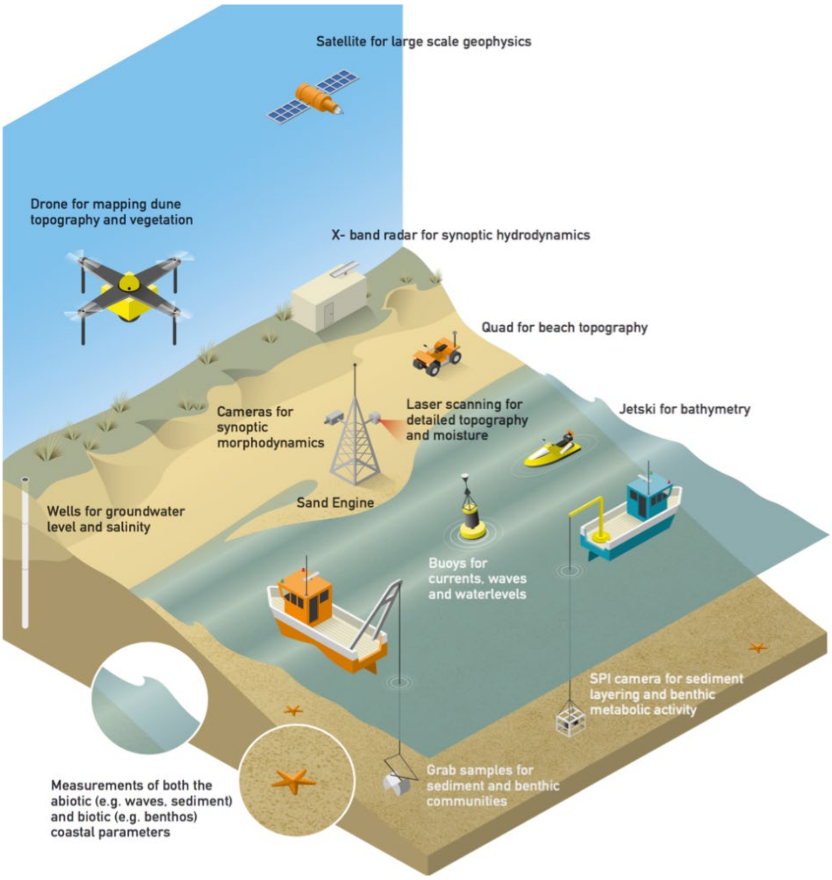

Fig. 2: ICON.NL data collection. The proposed schedule foresees in high-resolution measurements of waves, wind (meteo), currents, biota, sand motions and topography, augmented with numerical model data

To meet these challenging research requirements, the envisaged observatory (Fig. 2) foresees in a variety of data collections:

1. Remote sensing data (optical measurements, X-band radar, infrared cameras and LiDAR sampling), collected from drones, satellites and a shore-based stations)
2. In-situ data, covering regular surveys of bathymetry, continuous registration of nearshore water levels, wave parameters, flow velocities as well as meteorological variables, and simultaneous measurement of salinity, temperature and water pressure for ground water research. A Metabolic-SPI (Sediment Profiling Imaging) camera will be used for seafloor characterization.
3. Numerical data, obtained from the operational use of mature modelling systems to generate synoptic maps of nearshore flow, wave and sediment transport fields.

Fusion of model predictions and remotely-sensed / in-situ data will provide high-resolution temporal and synoptic information crucial for the interaction between science disciplines. For example, 3D current velocities and bed shear stresses are relevant information for understanding the spatial distribution of marine benthic species. Another example is that the model can supply spatiotemporal salinity distribution maps that can act as boundary condition for groundwater research. In this way, the open-source data corpus from ICON.NL will form a growing resource for fundamental coastal processes research and an enabler of interdisciplinary collaboration in the years to come.

Embedding of facility

The ICON.NL vision feeds into the long-term ambition to have concurrent data collection of different geophysical parameters for a sustainable budget. We envision continuing ultimately with only the remote sensing and numerical model data collection, removing most of the costly in-situ measurements. Considering the hands-on, operational nature of the research in this theme, ICON.NL will inherently lead to better links and improved collaboration between industries and academia. This is considered a strategically important spin-off of the proposed facility.

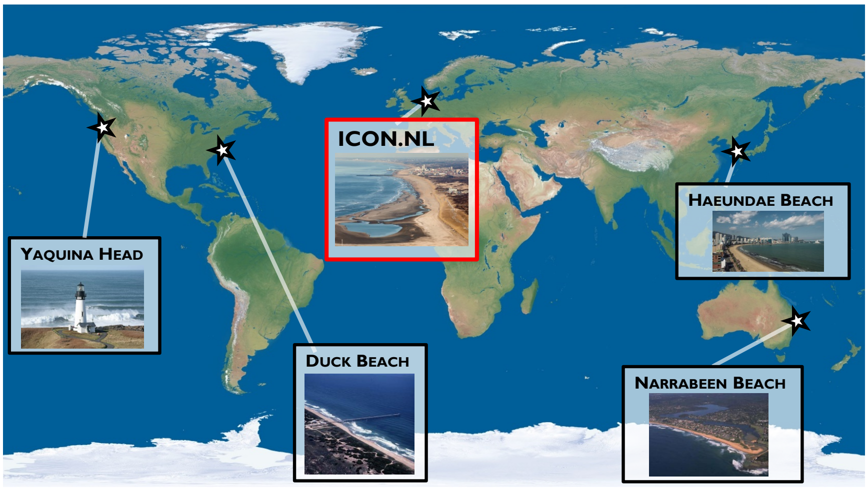

Fig. 3: Overview of international ICON sites

The trend towards high-resolution, internationally-connected coastline observatories is supported by the full Dutch coastal science community (united in the Netherlands Centre for Coastal Research, NCK), aligns with the strategic agendas of industry and government and is well embedded in international research frameworks. Collaborative arrangements with key research groups centered around world-class coastal field sites (Fig. 3) including Duck (NC, USA), Narrabeen (Australia), Haeundae Beach (South Korea) and Yaquina Head (OR, USA) are in place. The network is open to further expansion, particularly welcoming field sites with distinctive environmental conditions and a rich history of coastal monitoring and field data collections.

Conclusion

In this paper, we have made a plea for the focus of state-of-the-art, high-resolution monitoring efforts to a series of distinctive coastal sites worldwide, as part of an International Coastline Observatories Network (ICON). We are presently working on the establishment of a Dutch Observatory at the Sand Engine Delfland site, based on the combined use of remote sensing observations, in-situ measurements and numerical model predictions. The facility will be built on the basis of open-access protocols, to promote data exchange and facilitate research across several sites. Given the unique opportunities for fundamental research as well as interdisciplinary collaboration, we are convinced the ICON approach benchmarks the future in data sampling for coastal science, engineering and management.

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