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Coastal dynamics of Northern Australia – Insights from the Landsat Data Cube

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ABSTRACT

We demonstrate the capacity of detailed time-series of remotely sensed data to identify notable changes and trends in coastal morphology and vegetation over the last three decades, and illustrate how these data can help identify drivers of change, and areas that require further investigation. Time-series analysis (1987–2016) of the Australian Landsat archive is enabled by the Australian Geoscience Data Cube (AGDC), in which the data has been processed and restructured. We use Hovmoller plots to graphically display this time series for three test sites on the tropical coast of northern Australia. Initial results reveal distinct differences between sites: 1. Abrupt loss of mangrove cover (2004, 2006), which clearly relates to the passage of cyclones (Junction Bay); 2. Gradual seawards expansion of mangrove (1987–1996), and subsequent rapid narrowing of the mangrove zone (2013–2016; Burketown); 3. Minor seawards expansion of mangrove (1987–2004) in a stable embayment (Darwin Harbour). The density and duration of the time series enables clear links to be made to recorded events (e.g. cyclones), and identifies focus areas that exhibit unprecedented patterns of change (e.g. loss of mangrove) where regional or global environmental processes may be driving local change.

1. Introduction

The coastal zone includes a variety of important ecosystems, continues to undergo rapid change due to development and population increase, is often exposed to natural hazards and is experiencing the impacts of a changing climate. These pressures have raised concern for degradation of coastal environments globally (Sekovski et al., 2012).

Coasts exhibit geomorphic change over seasonal, annual and multidecadal timescales (Cowell and Thom, 1994; Splinter et al., 2013). Therefore, long-term coastal observational data, that span multiple years and decades, are required to robustly characterise the dynamics of these environments (Short and Trembanis, 2004). However, coastal observational data are not widely available and are often limited in spatial and temporal resolution (Splinter et al., 2013).

Remote sensing is recognised as a fundamental and cost effective tool for establishing coastal environmental baselines and monitoring, for example measuring shoreline change (Shetty et al., 2015), monitoring seagrass (Lyons et al., 2012) and mapping intertidal areas (Murray et al., 2012). Landsat data provide comprehensive, regular coverages of the coast, and the Australian Geoscience Data Cube (A-GDC) provides Landsat data as regular grids of calibrated measurements of surface reflectance, enabling these observations to be accessed and effectively applied to assessments of environmental change (Mueller et al., 2016; Lewis et al., 2017).

Here we present the results of the application of Landsat imagery in the AGDC for remotely sensing coastal environmental change. We employ the time-series to analyse the spatio-temporal dynamics of coastal environments in northern Australia, where there are few observational records. We demonstrate the potential of this approach for identifying hot-spots of change, interpreting change events and trends, and to support focussing more detailed investigations.

2. Study area

The tropical northern coast of Australia generally has a high level of environmental integrity due to its remoteness, very low population density, and little-developed state (Brooke et al., 2012; Fig. 1). Coastal ecosystems here provide habitat for a range of threatened, endangered, and migratory species (Department of the Environment and Energy, 2016). This region has also been identified as an area of national priority for further economic development (http://northernaustralia.gov.au/), highlighting the need for environmental baseline information.

3. Methods

Measurements of land surface reflectance were extracted from the

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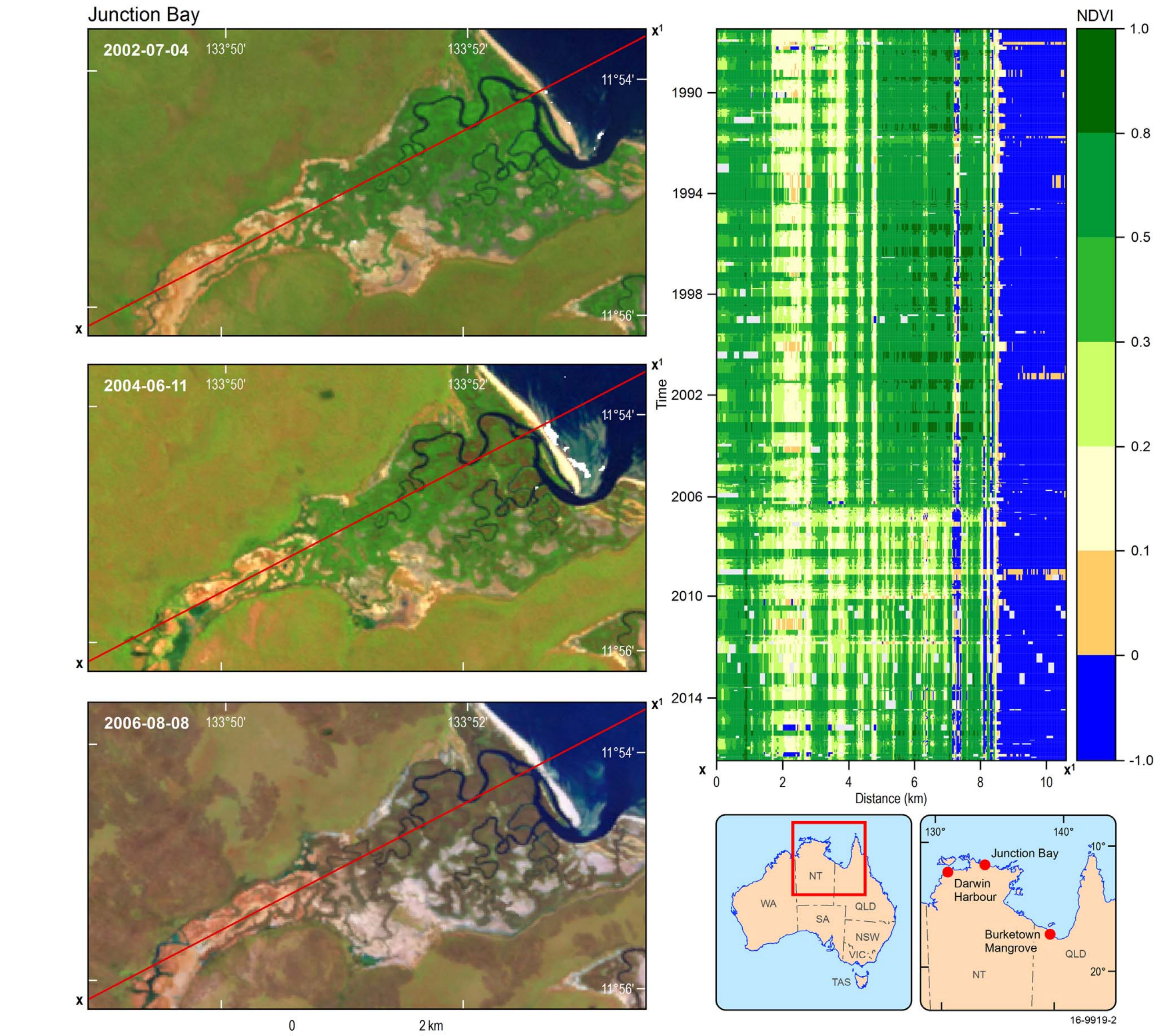

Fig. 1. Location of the study sites (inset maps). The time-series for Wurugoij Creek in Junction Bay is displayed in the Hovemoller graph on the right. The graph provides a detailed visualisation of the 29 year Landsat time-series along a transect ($x - \times^1$) through the estuary. The x-axis is distance along the transect, y-axis is time; colours represent NDVI values (white = invalid pixels). On the left are three representative Landsat true-colour images that depict conditions prior to and following a severe cyclone in 2006.

open-access Australian Surface Reflectance Grid (ARG-25) that is derived from the Landsat archive in the AGDC (Lewis et al., 2016; http://www.ga.gov.au/scientific-topics/earth-obs/satellites-and-sensors/landsat/arg25). Australian Landsat data has been acquired continuously since 1987 by sensors on the Landsat 5, 7 and 8 satellites (resampled to 25 m resolution; from 16–8 –days frequency of observation). In brief summary, to produce the ARG-25, all of these Landsat observations (pixels) were converted to nadir view angle corrected, BRDF corrected, atmospherically corrected surface reflectance using the methods described in Li et al. (2010). These calibrated data are intercomparable between the various Landsat instruments (ETM, ETM+, and OLI).

The ARG-25 also includes per-pixel metadata which flags cloud and cloud shadow affected observations based on the ACCA (Irish et al., 2006) and Fmask (Zhu and Woodcock, 2012) algorithms. These products are generated for the full archive in an integrated High Performance Computing – High Performance Data environment (details in Lewis et al., 2016, 2017). Image data are segmented into 1° × 1° 'data tiles' covering the Australian continent (based on an equal angle global grid tessellation). Importantly, each data tile in the AGDC has a specific date of acquisition and its geospatial footprint is consistent for all satellite observations of the same area throughout the time-series (Lewis et al., 2016). These data tiles are therefore convenient 'time stacks' of corrected Landsat imagery which can easily be sampled to produce time-series of surface reflectance measurements for any chosen point, or for a sequence of points.

Time-series analysis was undertaken for three sites that represent the broader areas from which the samples are drawn, where mangrove communities have previously been mapped, and that exhibit different shoreline morphology and vegetation patterns (Fig. 1). We deliberately utilise a simple but robust index (Normalised Difference Vegetation Index, NDVI; Kuenzer et al., 2011) to enhance discrimination of fundamental features (e.g. mangrove, exposed sediment, water) in graphical visualisations of the Landsat time series. Our intention is to demonstrate the potential of the AGDC for establishing dynamic baselines in terms of these broad biophysical features of the coast (e.g. Murray