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Between the Tides: Modelling the Elevation of Australia's Intertidal Zone

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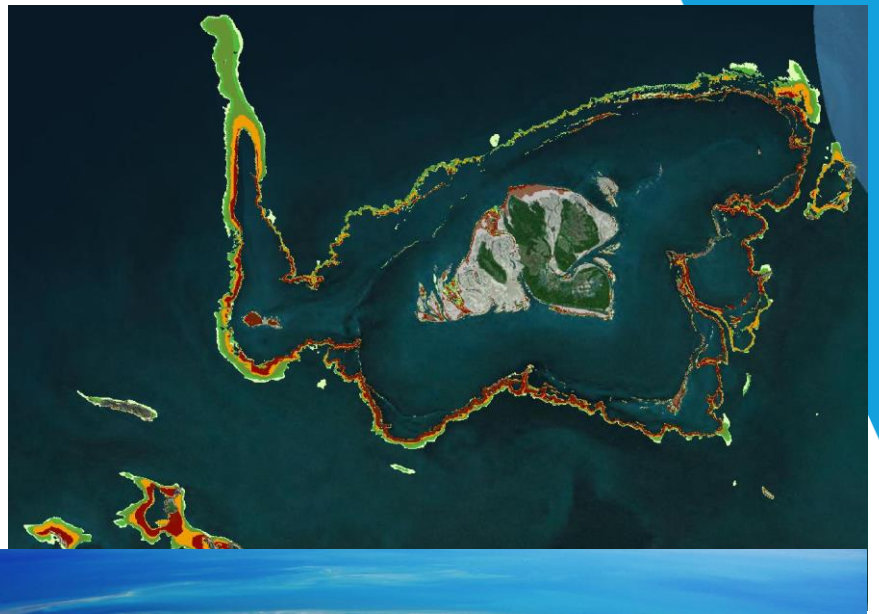
Presentation Outline

- Digital Earth Australia (DEA)
  - Background
- Intertidal & Coastal Applications
  - EO timeseries and tidal modelling
  - Intertidal Extents Model (ITEM)
  - National Intertidal Digital Elevation Model (NIDEM)
  - Coastline applications
- Access and Interaction



The Digital Earth Australia (DEA) Program

Has its origins in the 'Unlocking the Landsat Archive project', kick-started by the public release of the Landsat archive in 2009 by the USGS.

The first prototype was the Australian Geoscience Data Cube (AGDC), a collaborative project between GA, CSIRO and the NCI.

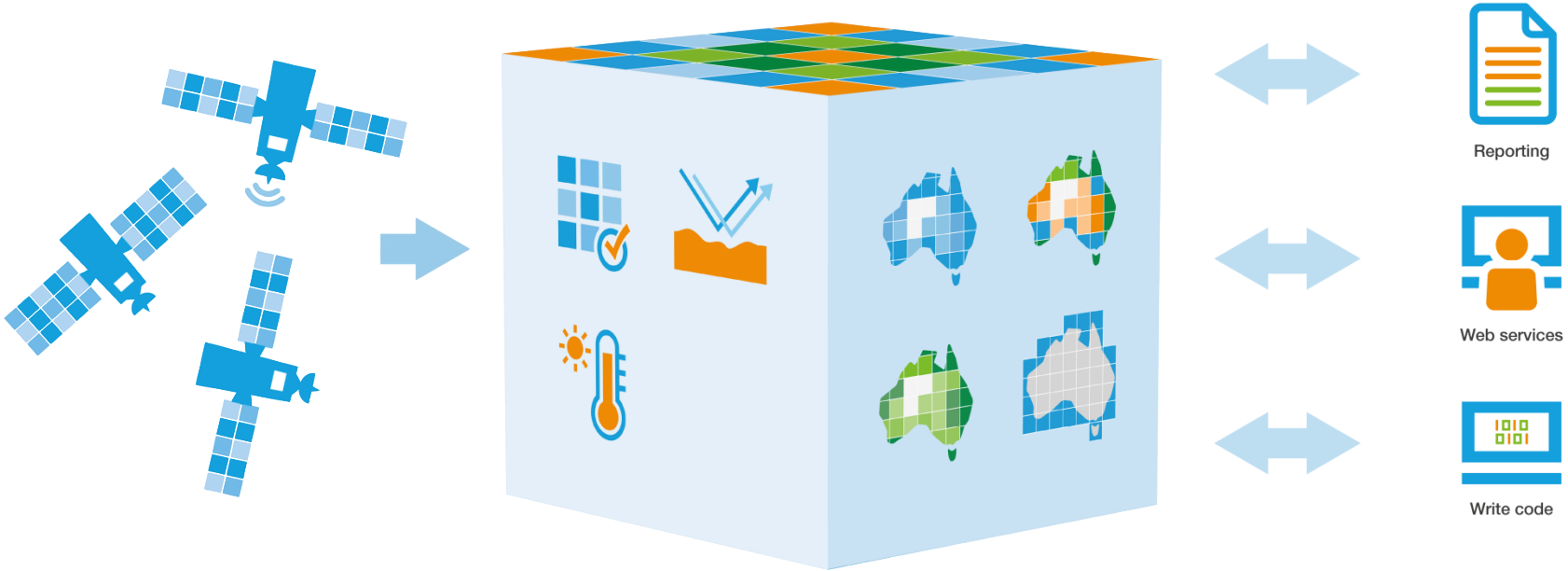
This developed into the Open Data Cube (ODC) initiative, of which DEA is an implementation

Secured ongoing government funding in the 2018/19 budget of $13m per year to deliver robust data infrastructure, standardised services and information products to:

1. Increase the efficiency and effectiveness of Australian government programs and policies that need accurate and timely spatial information on the health and productivity of Australia's landscape.

2. Enable Australian business to quickly capitalise on open data, and create new capabilities to increase efficiency, productivity and employment opportunities.

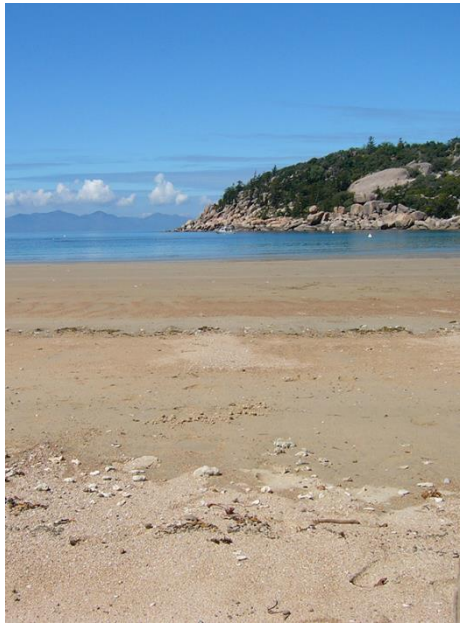
What is Digital Earth Australia?



The Intertidal Extents Model (ITEM)

Objective: To model the extent and topography of the intertidal flats of Australia's coastline utilising 30 years of the Landsat archive

How and why do we want to map the intertidal zone?

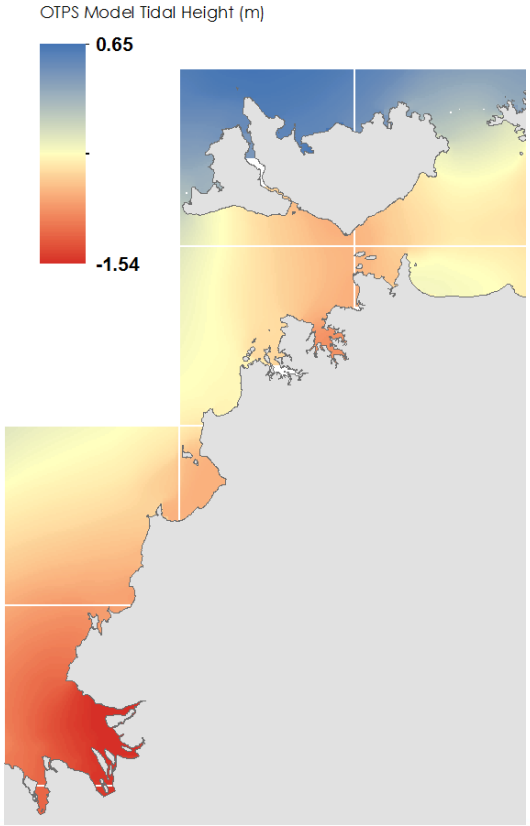


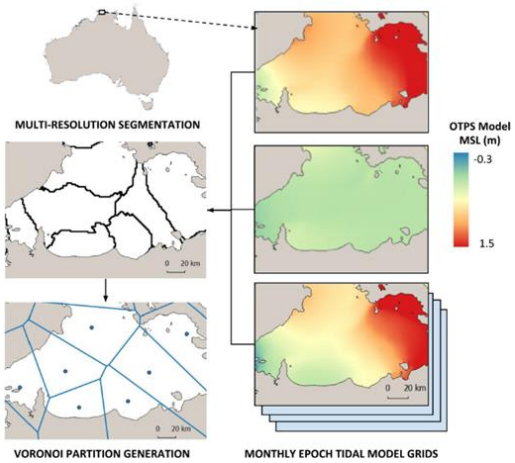
- An important coastal ecosystem, characterised by high productivity and biodiversity and providing habitat for migratory shorebirds worldwide
- Provides critical coastal protection from extreme storm events, and is often a component of the coastal geomorphologic system around high value commercial asset sites such as ports.
- Capturing information on the extent and topography of the intertidal zone, particularly at a continental scale, is a challenging and costly exercise.
- The physical environment makes traditional surveying methods difficult to implement, and acquisition of airborne elevation data (LiDAR etc) is expensive and subject to tidal regimes of the study site.

Remote sensing is a cost effective option, but still subject to tidal regimes and environmental factors. Recent single image analysis (*Dhanjal-Adams et al., 2016*) has estimated Australia's tidal flats at a **minimum area of 9,855km^2**


1987

Continental Scale Tidal Modelling



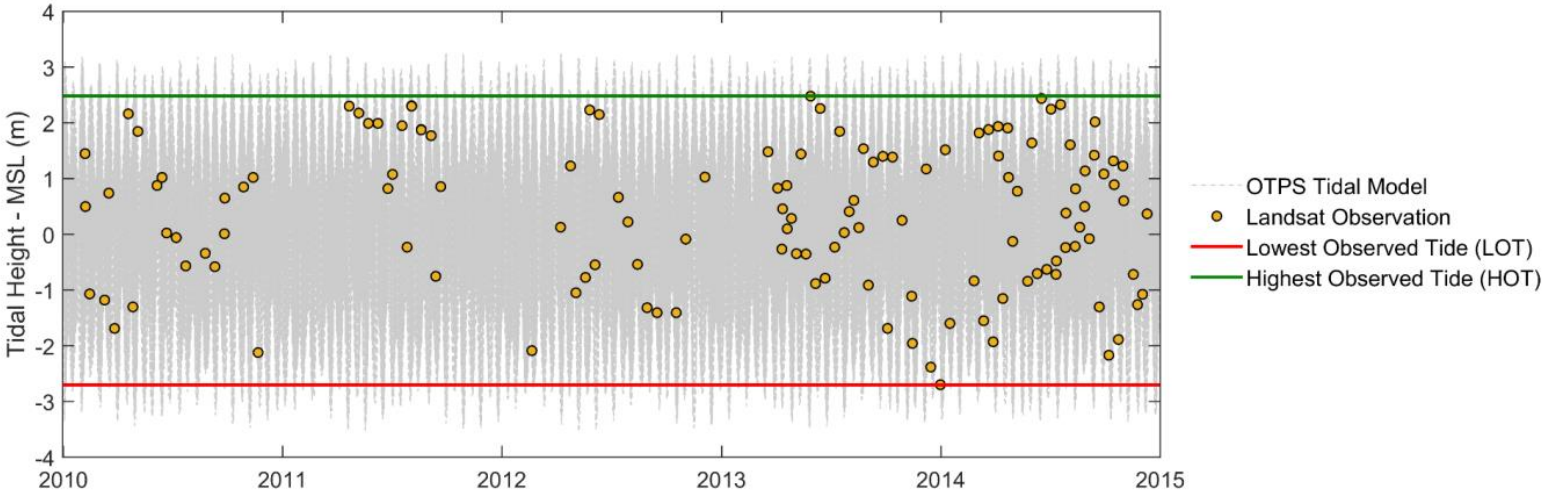


Oregon State Tidal Prediction Software (OTPS) *(Egbert and Erofeeva, 2002)*

- A tidal harmonics based regionally validated model with <5cm RMSE misfit
- Our testing against the Hydrographic Office Austides record show a RMSE misfit of ~10-15cm
- We use the OTPS TPX08 model, consisting of a multi-resolution bathymetric grid solution, with a 1/6° solution in the global open ocean, and a 1/30° local resolution solution to improve modelling in complex shallow water environments.

Sagar, S.; Phillips, C.; Bala, B.; Roberts, D.; Lymburner, L. 2018 Generating Continental Scale Pixel-Based Surface Reflectance Composites in Coastal Regions with the Use of a Multi-Resolution Tidal Model. Remote Sensing. 10, 480.

The Observed Tidal Range (OTR)



A sun-synchronous sensor – observes at the around the same time of the day for each observation

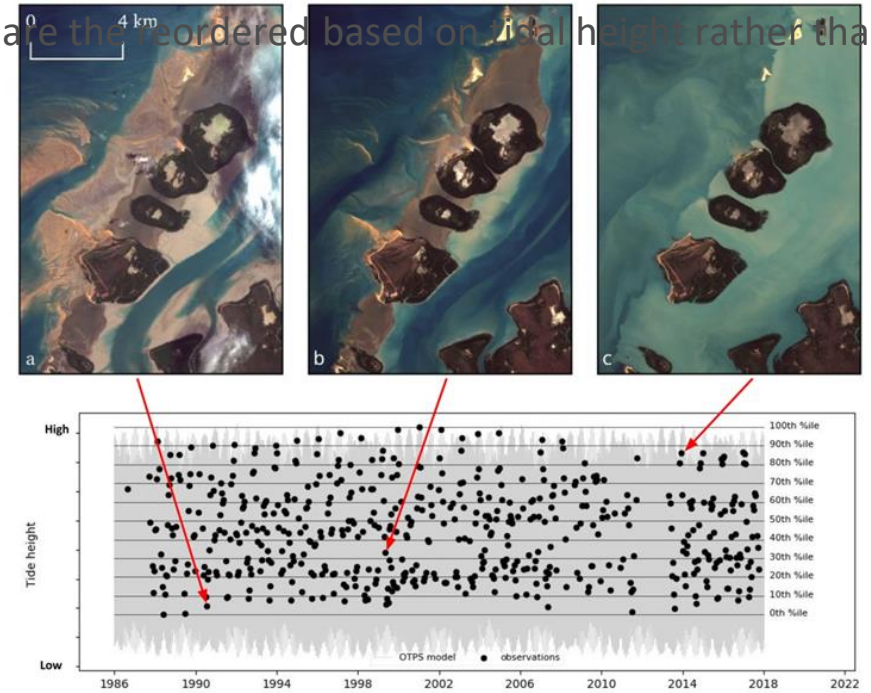
This means that even with tidal variations, we most likely will only observe a portion of the full tidal range

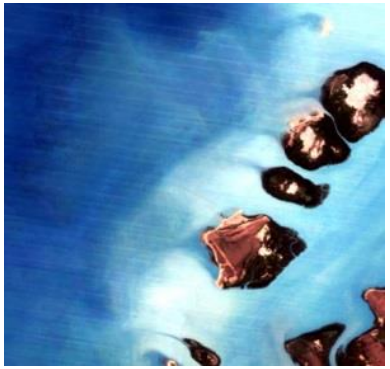
We can characterise this as highest (HOT) and lowest (LOT) observed tide

The Intertidal Extents Model (ITEM) Process

- Each stack of observations is attributed with a tidal height utilising the OTPS model
- Observations are then reordered based on tidal height rather than time

Lowest Observed Tide (LOT)

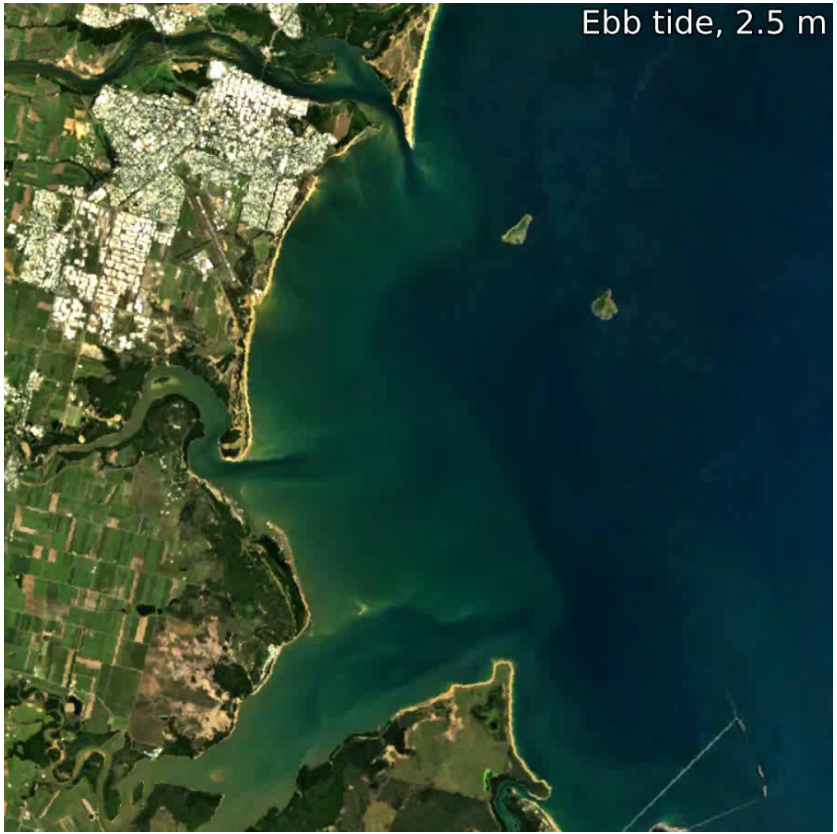




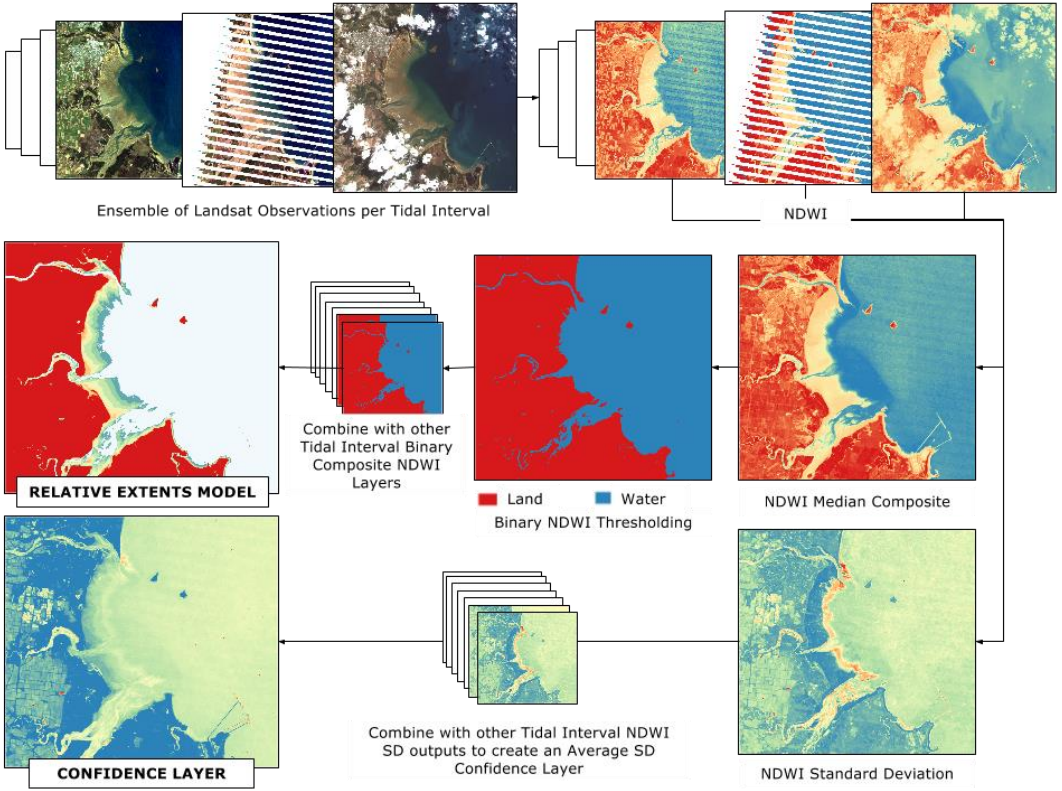
Highest Observed Tide (HOT)

- The Observed [illegible] to create ensemble stacks of observations for each 10% of the range

Mackay Queensland – Full Tidal Cycle

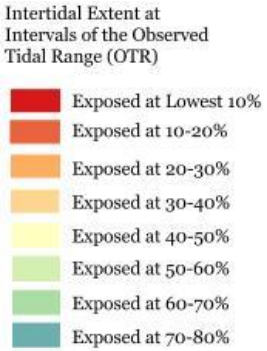


The Intertidal Extents Model (ITEM) Process



Sagar, S., Roberts, D., Bala, B., Lymburner, L., 2017. Extracting the intertidal extent and topography of the Australian coastline from a 28 year time series of Landsat observations. Remote Sens. Environ. 195, 153–169.

The Relative Extents Model



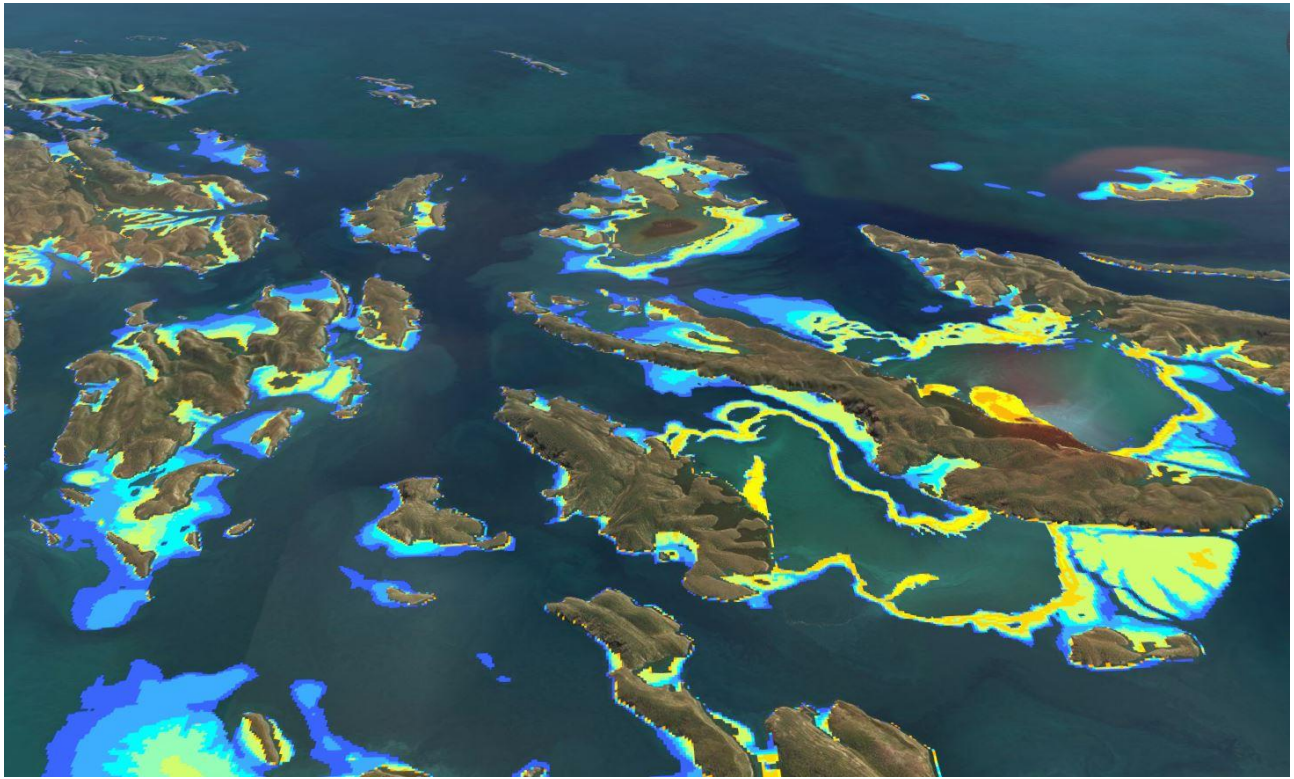
Models the Extent and Topography of the Intertidal Flats

Layers values reflect the spatial extent of the exposed intertidal land surfaces at intervals of the OTR

Modelled up to the highest 80% of the OTR

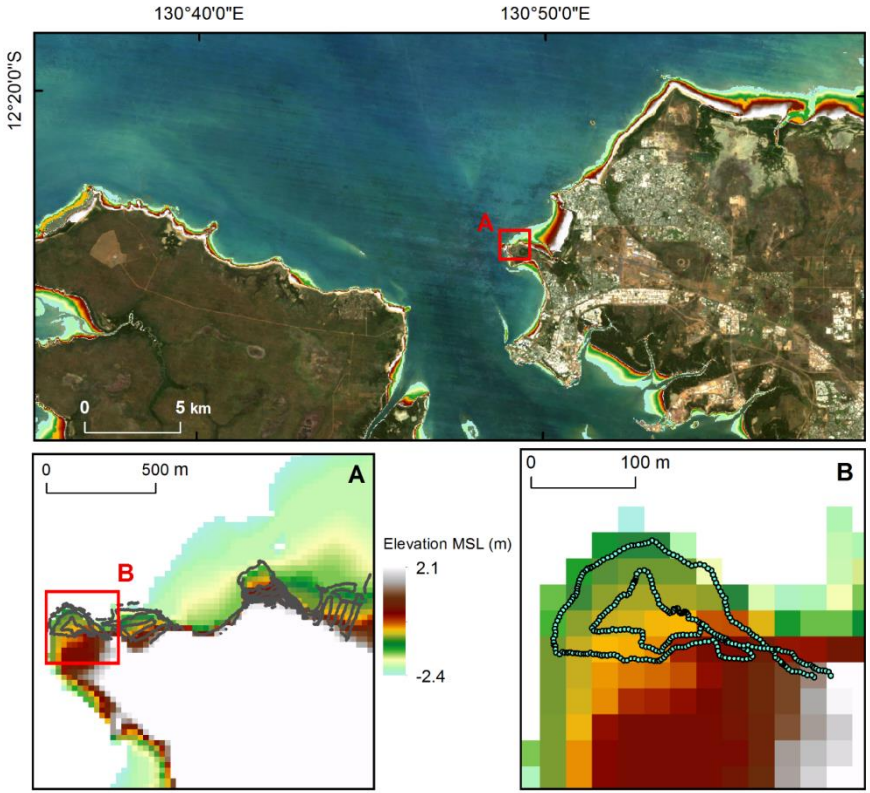
Roebuck Bay, Western Australia

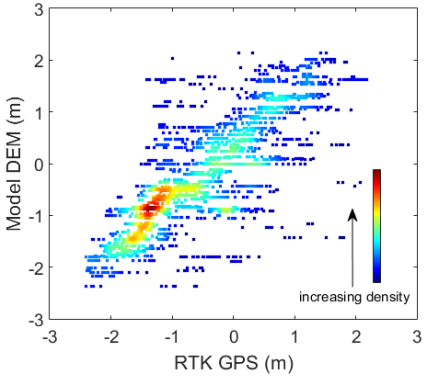
ITEM – Exposed Reef Structures

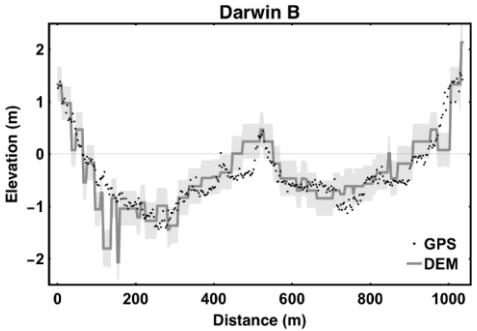


Talbot Bay, The Kimberley, Western Australia

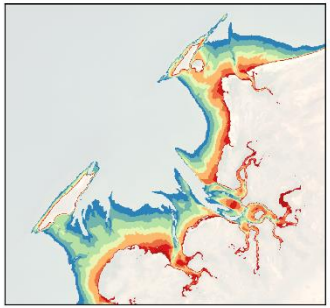
Turning ITEM into a DEM - Darwin, Northern Territory



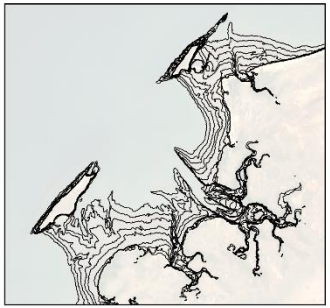




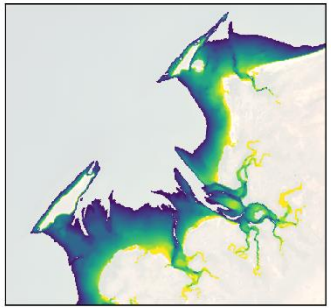
The National Intertidal Digital Elevation Model (NIDEM)



10% intervals of the tidal range mapped from 30 years of Landsat satellite imagery



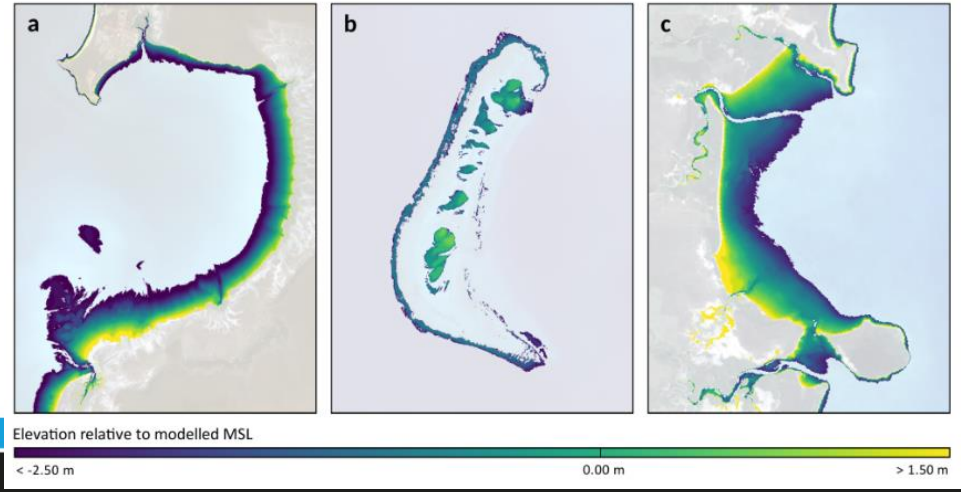
Waterline contours extracted and assigned median tidal heights for each 10% interval



Transforms the relative topography of ITEM into an elevation model relative to Mean Sea Level (MSL)

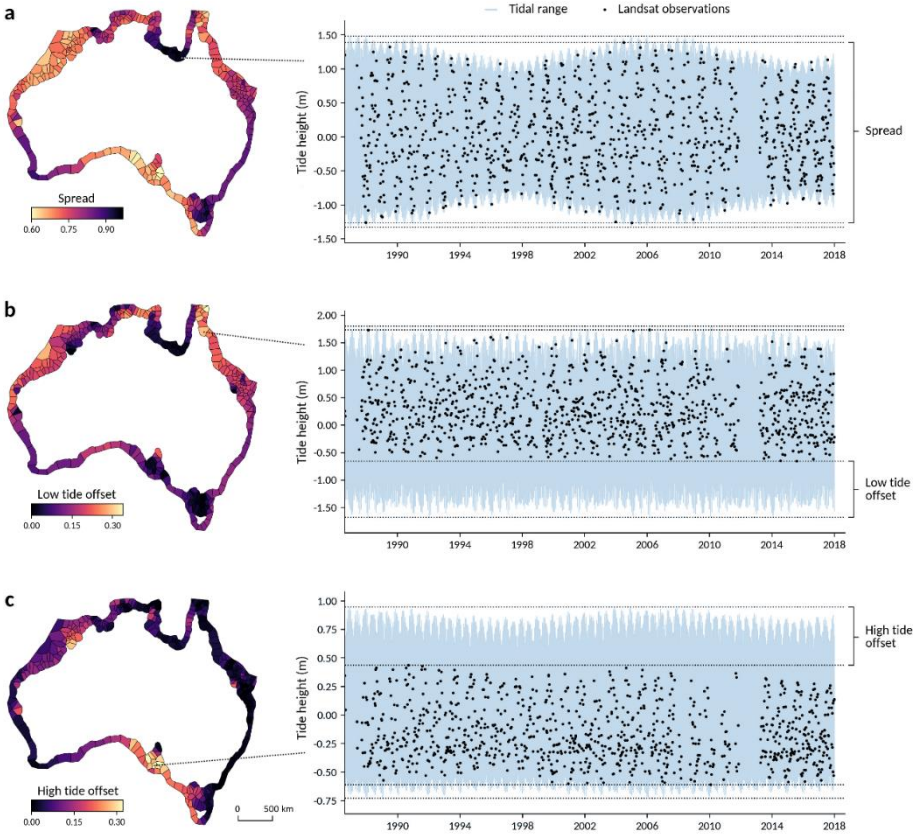
Extracted waterline contours are assigned tide heights, using the median of the heights attributed to the ensemble of images in each tidal stage interval

Contours are then interpolated back to the original 25m resolution of the ITEM model



Bishop-Taylor, R., Sagar, S., Lymburner, L., Beaman, R.J., 2019. Between the tides: Modelling the elevation of Australia's exposed intertidal zone at continental scale. Estuarine, Coastal and Shelf Science 23, 115–128.

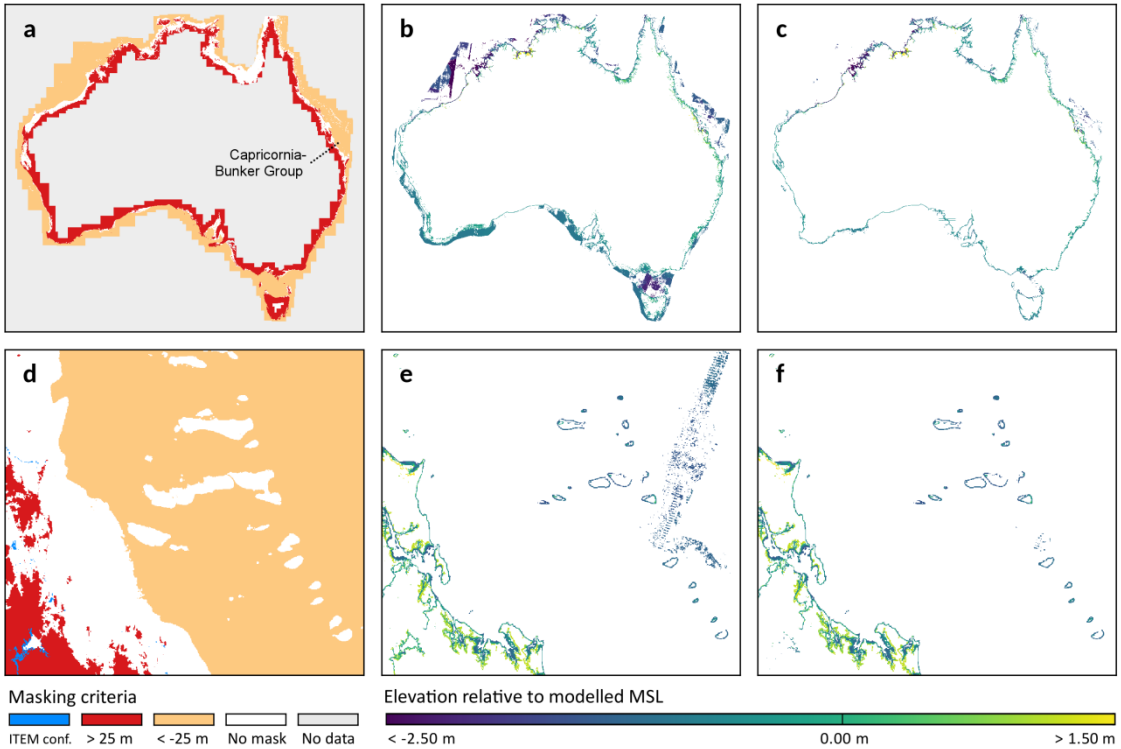
NIDEM Products – Evaluating the spread of Observations



Information layers which describe the spread and offset of the tidal stage distribution at each location of the model

Can aid users in interpreting the elevation model and integrating with other data layers

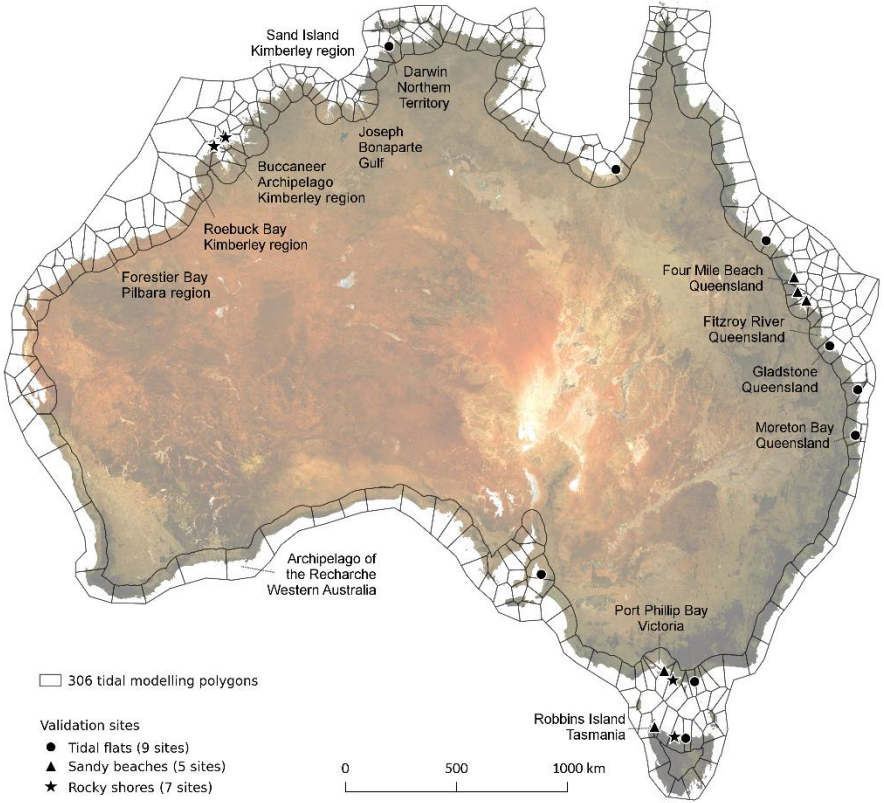
Filtering NIDEM for Offshore Reef Coverage



On shore elevation data and lower resolution bathymetry data is used to filter using extreme values in the model extents

Cleans the residual noise from the model (persistent glint, data gaps in the archive) to enable improved coverage of exposed reef systems

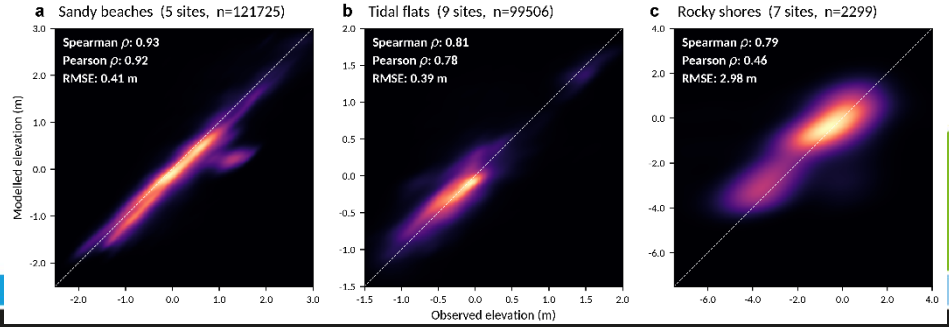
NIDEM Validation



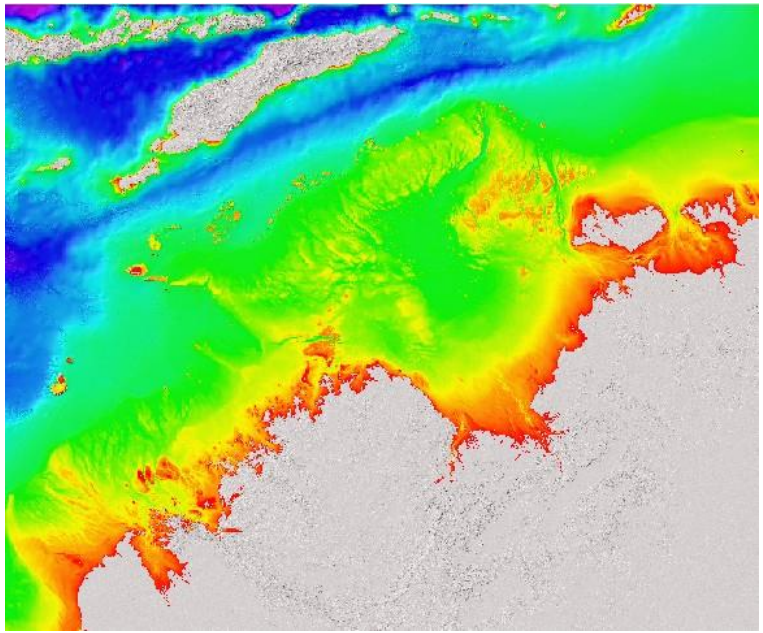
Validated using LiDAR, RTK GPS and multibeam data

Strong correlation with ~0.40m RMSE over sandy beach and tidal flat enviroments

Poorer fit over on-shore reefs is explained by the delayed draining and remnant water in reef lagoons where this data was located



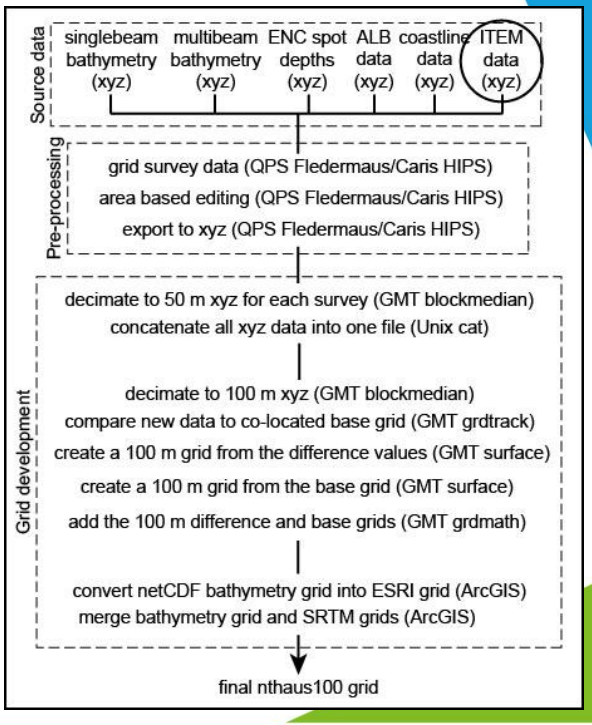
Integrating NIDEM into the Northern Australian 100m Bathymetry Grid



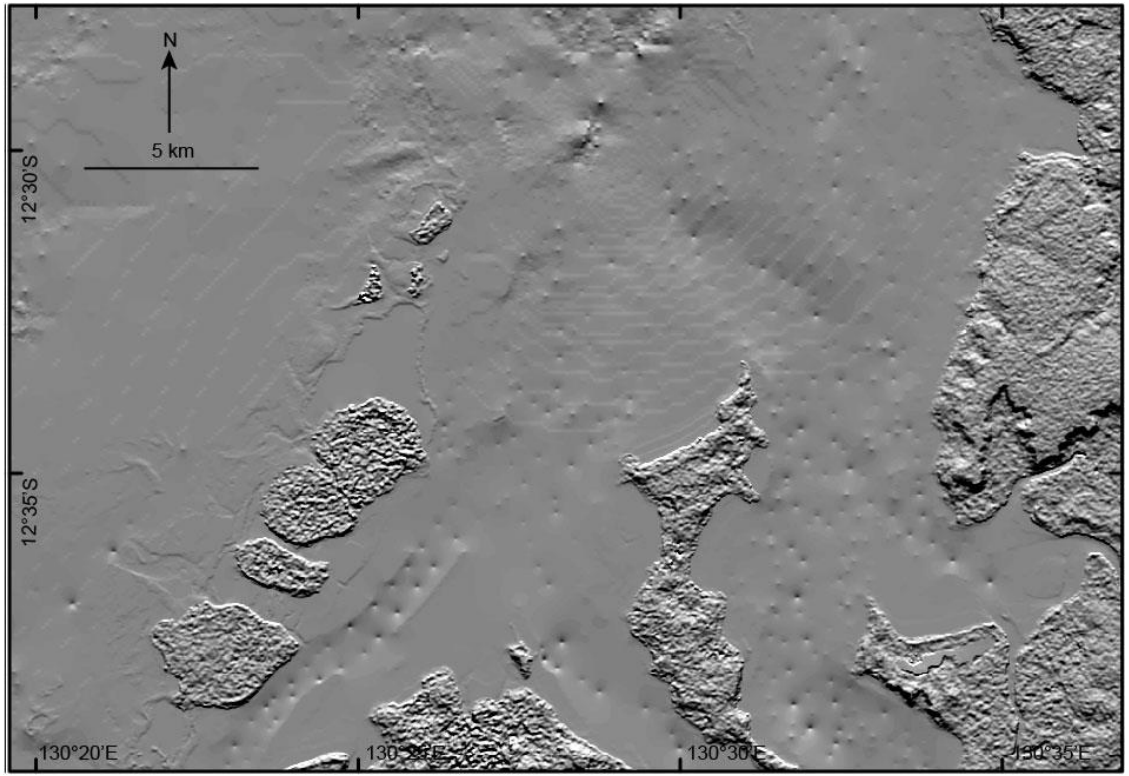
Work completed by Dr Robin Beaman (JCU) and Geoscience Australia

NIDEM is effective in these sometimes highly turbid areas where water column Satellite Derived Bathymetry methods are restricted.

Tidal ranges of over 6m, and intertidal flats 10's of km wide



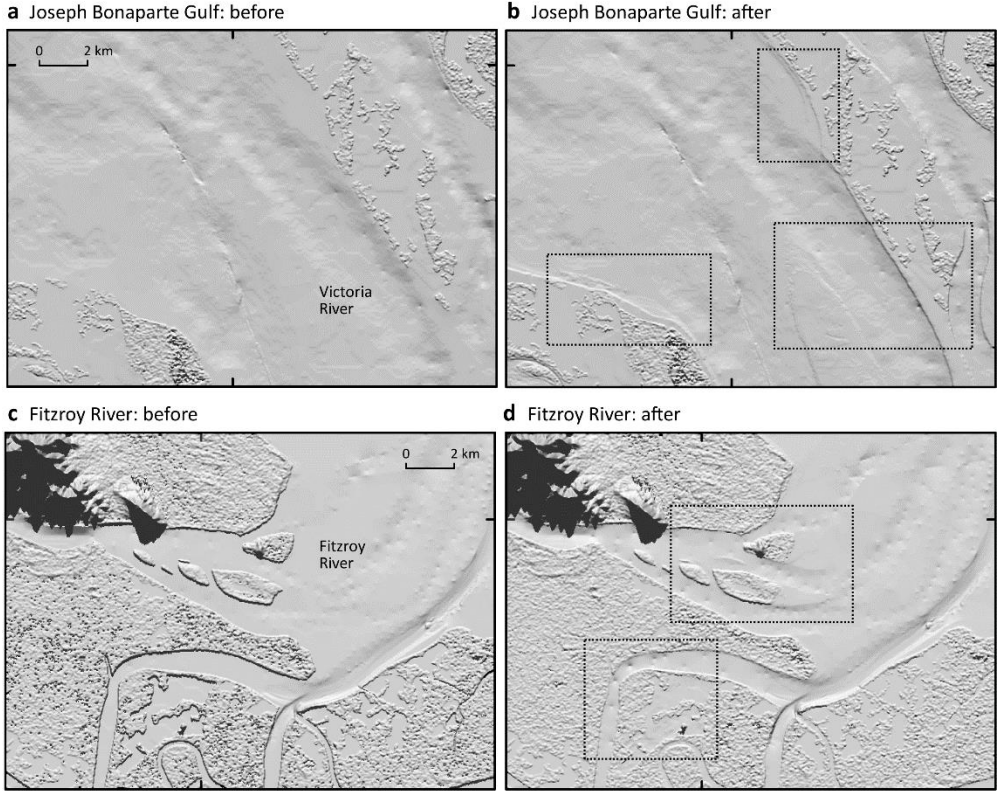
Filling in the (very) shallow water gap



NIDEM is effective is delineating very shallow reef features, shoals and platform features that can be missed in coarser resolution and deeper water surveys.

Acts as a complementary data source to produce a more realistic land/sea interface in the grid

Elevation data in turbid waters



Can be effective in regions where optical SDB methods, or even LADS, may struggle

Where to next?

- Improvement of the tidal modelling to incorporate extreme events and sea level forcing (UWA model)
- Incorporation of Sentinel 2
- Open source workflow so users can build their own optimised local model.

What NIDEM is not designed for….

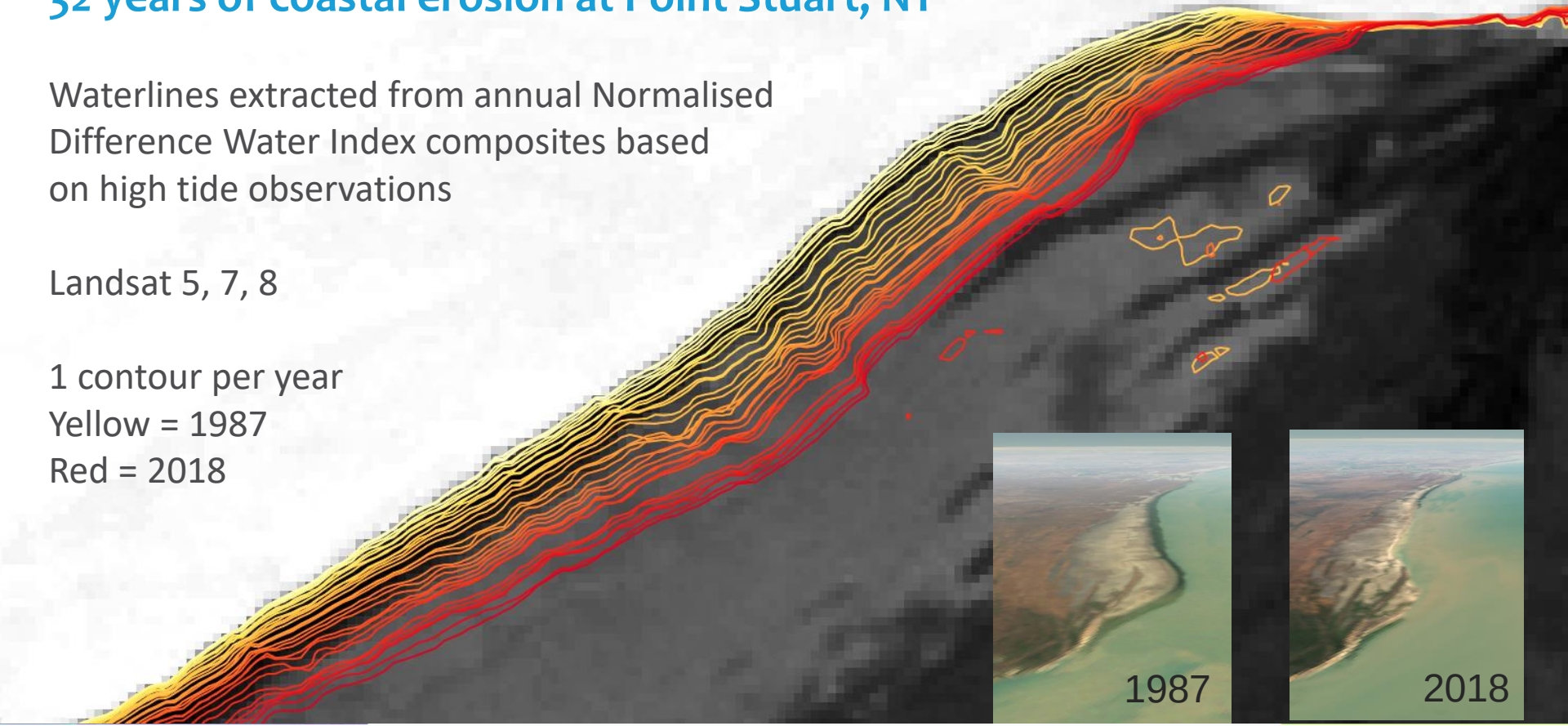
- Modelling the profile or elevation of areas that aren't inundated in the tidal cycle (ie. beach profiling)
- Of limited use in micro tidal regions with a steep sloping shoreline or breaking waves
- Cannot model obstructed intertidal regions, ie vegetation cover, mangroves

32 years of coastal erosion at Point Stuart, NT

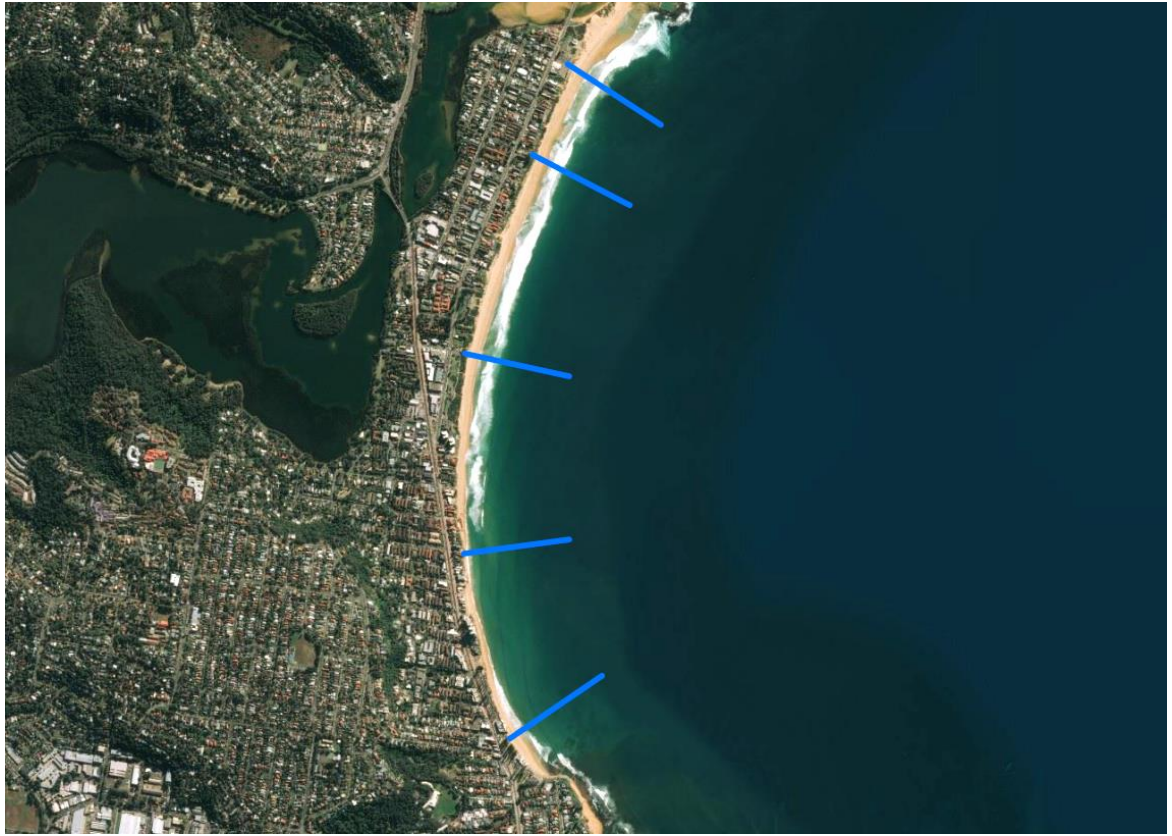
Waterlines extracted from annual Normalised Difference Water Index composites based on high tide observations

Landsat 5, 7, 8

1 contour per year
Yellow = 1987
Red = 2018



Narrabeen Beach validation data



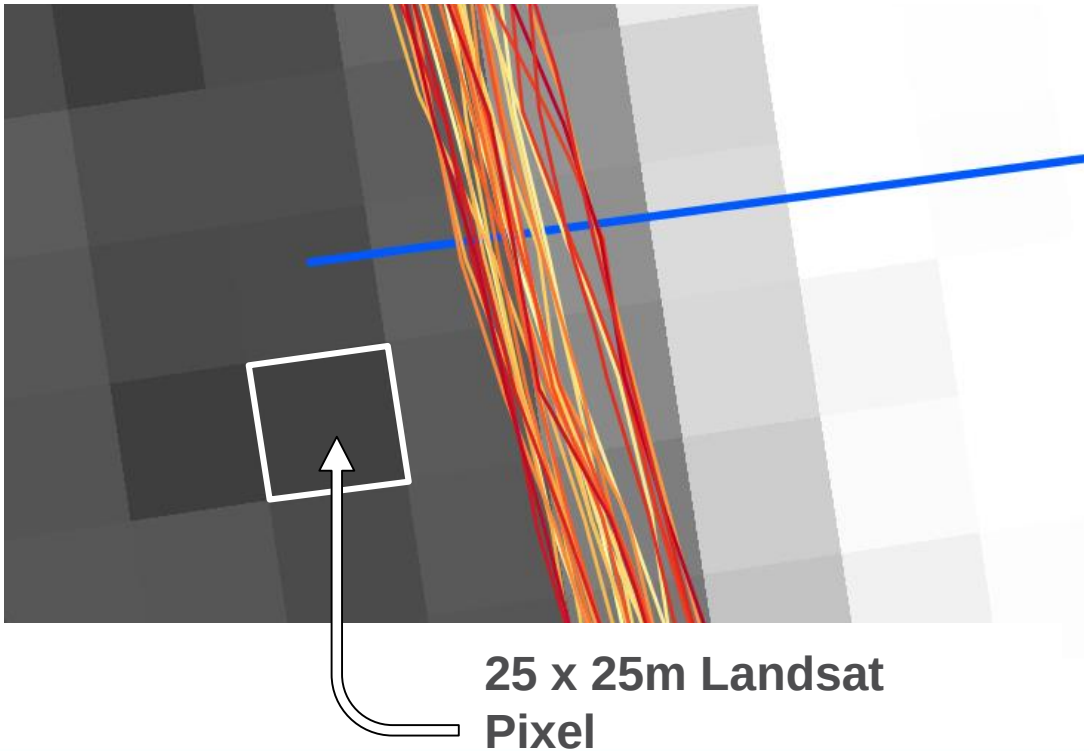
- 5 transects
- Elevation and beach width every month from 1988 to 2016
- Rare example of truly long-term monitoring program

Annual shorelines from Landsat

- 1 shoreline contour per year based on Landsat 5, 7 and 8 NDWI

1987-2018

Annual shorelines from Landsat



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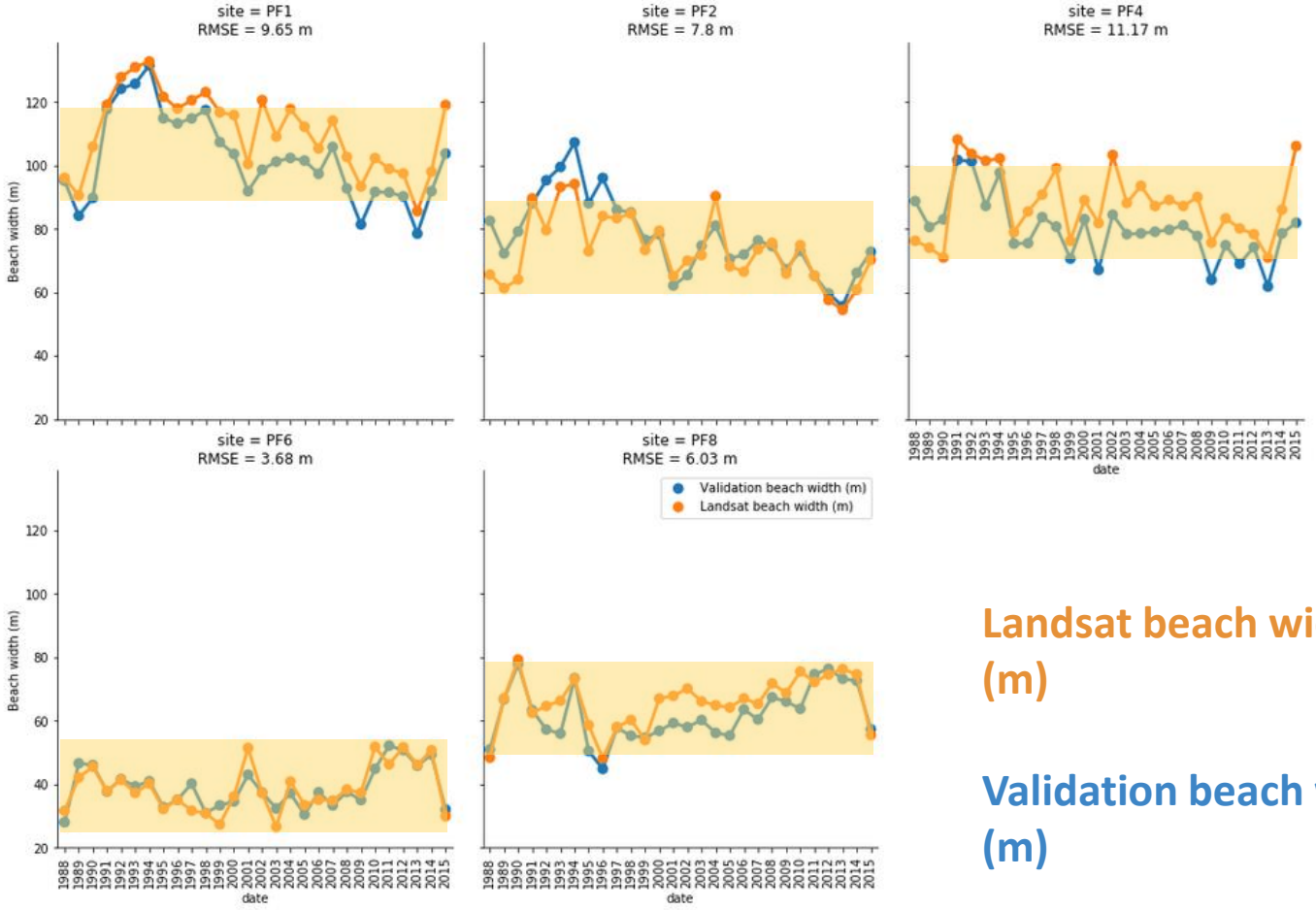
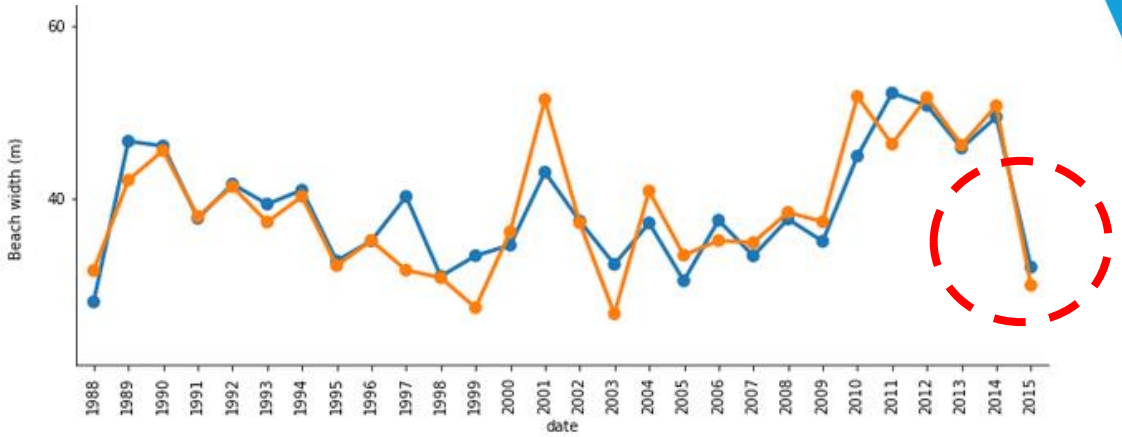
1987-2018



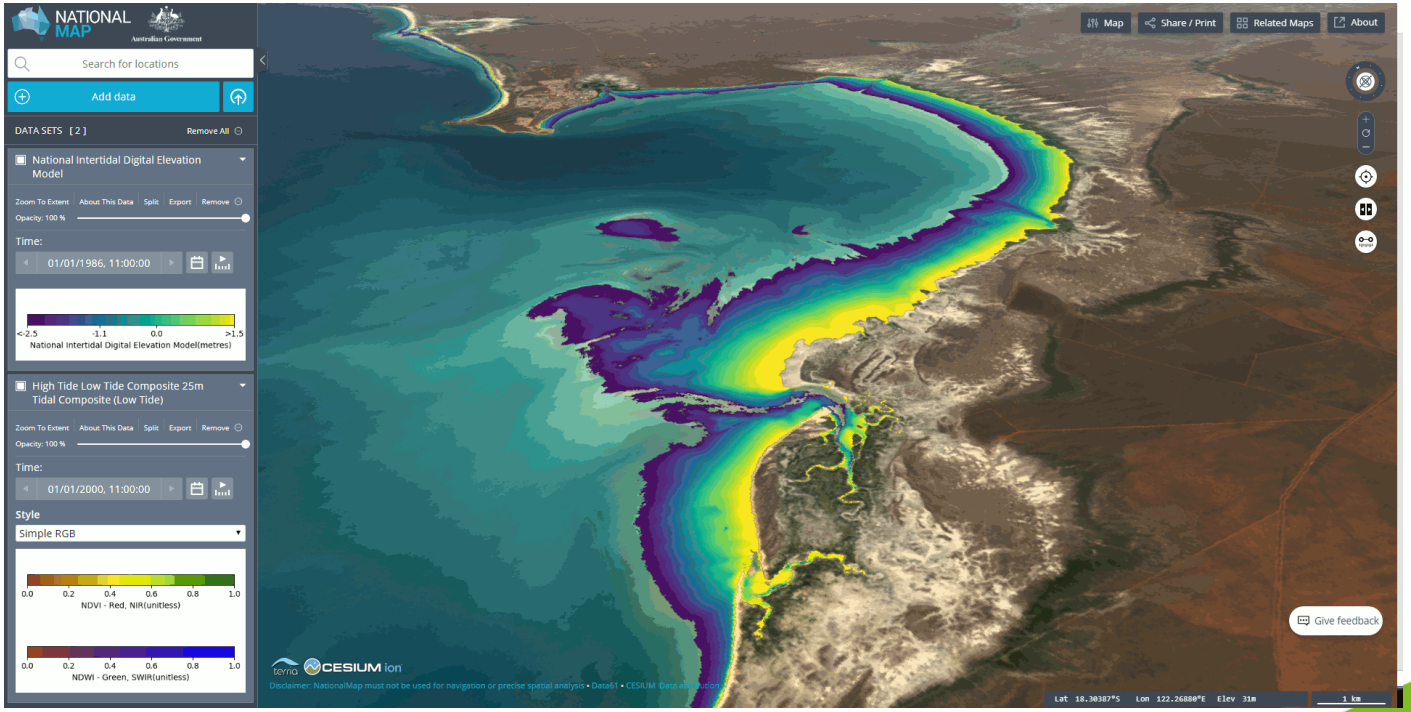
Landsat beach widths (m)

Validation beach widths (m)



Access and Interaction – nationalmap.gov.au

https://nationalmap.gov.au/#share=s-jaoN3YJv9GPNg57X5bkxSVYVD88



Access and Interaction – www.ga.gov.au/dea/products

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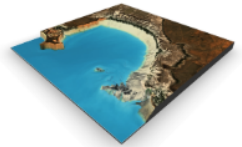
National Intertidal Digital Elevation Model

The National Intertidal Digital Elevation Model (NIDEM) is a national dataset that maps the three-dimensional structure of Australia's intertidal zone - the area of coastline exposed and flooded by ocean tides. The intertidal zone supports many important but threated ecological habitats including tidal flats, sandy beaches, and rocky shores and reefs.

NIDEM provides a first-of-its kind source of intertidal elevation data for Australia's entire coastline. It is anticipated that NIDEM will assist in mapping the habitats of threatened coastal species, identifying areas of coastal erosion, planning for extreme events such as storm surges and flooding, and improving models of how sea level rise will affect the Australian coastline.



Tidal flats of Roebuck Bay, on the coast of the Kimberley region of Western Australia, visualised in three dimensions using NIDEM intertidal elevation data.

Further information

- View and access product interpretation tools via NationalMap. Select *Add data*, and then the *Surface Water and Marine/Tidal theme*.
- Download the data and product information

Intertidal Extents Model

The Intertidal Extents Model (ITEM) product utilises 30 years of Earth observation data from

Currently planning a DEA Coastal products workshop at GA for August 2019

Australian Government
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Further Information

www.ga.gov.au/dea/products

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Acknowledgments
Leo Lymburner (GA)
Claire Phillips (GA)
Robin Beaman (JCU)
Dale Roberts (ANU/GA)