# Coastal vulnerability and climate change adaptation in South Africa: Remote sensing challenges and opportunities

Dr Melanie Lück-Vogel
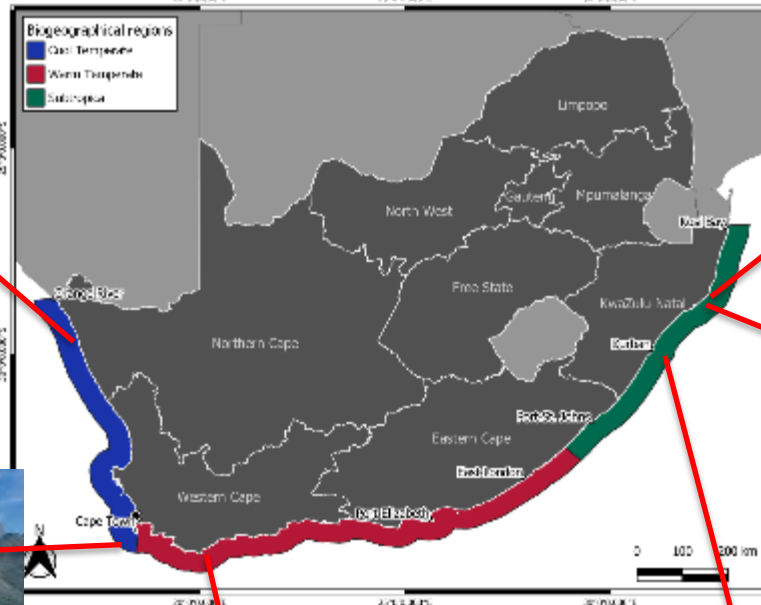CSIR Coastal Systems Research Group
Stellenbosch, South Africa

EU COMARE Conference
Saint Malo, France (hybrid)
19 May 2022

South Africa – Setting the scene

- 3000 km of coast
- 300 estuaries
- 3 Biogeographic regions

South Africa

Biogeographical regions
- Cool Temperate
- Warm Temperate
- Subtropical
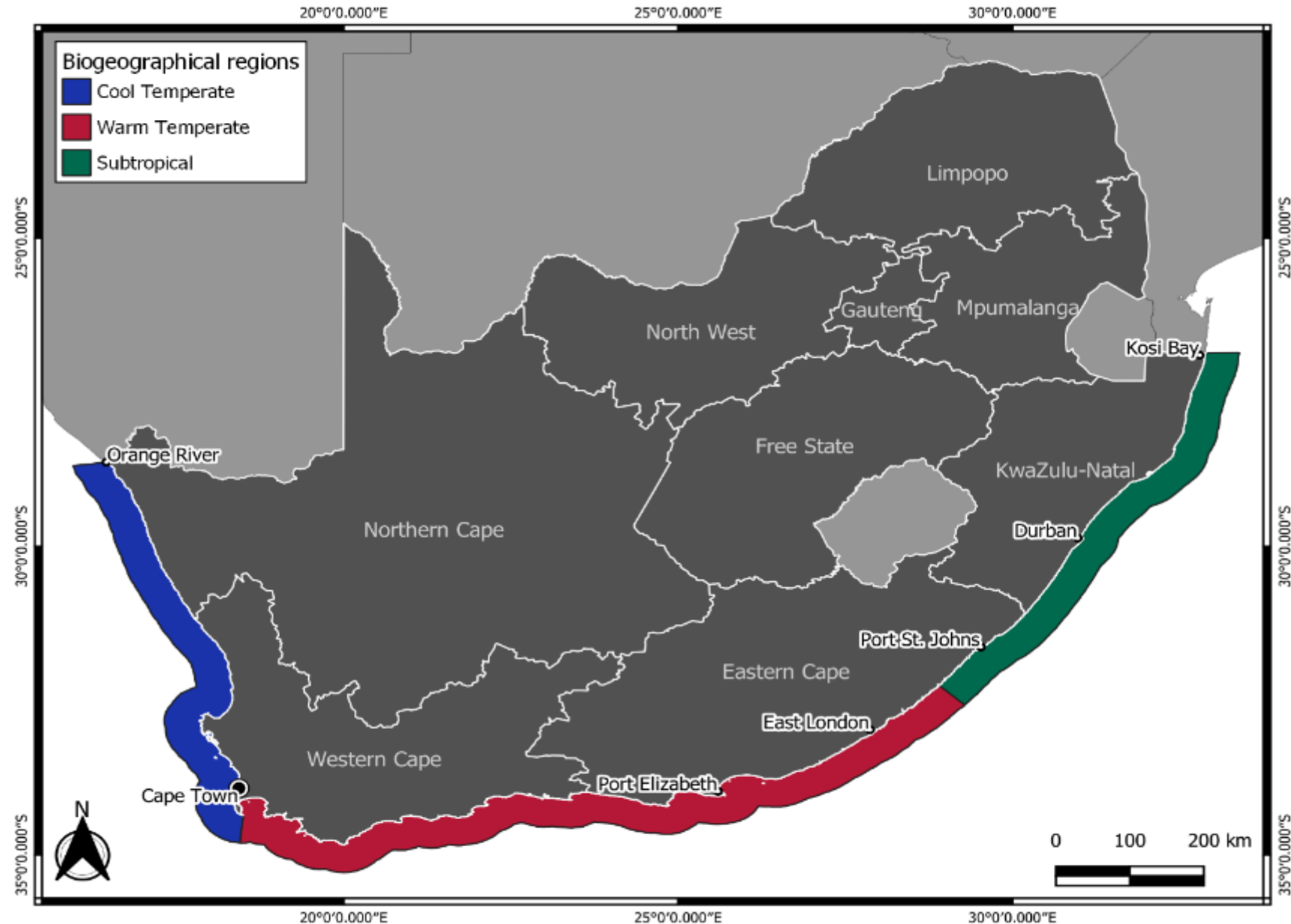
South Africa – Setting the scene

Pristine 300m high dunes with coastal forest

Sparsely populated desert

Cape Town Metropol & Port

Pristine strandveld vegetation

Durban area residential
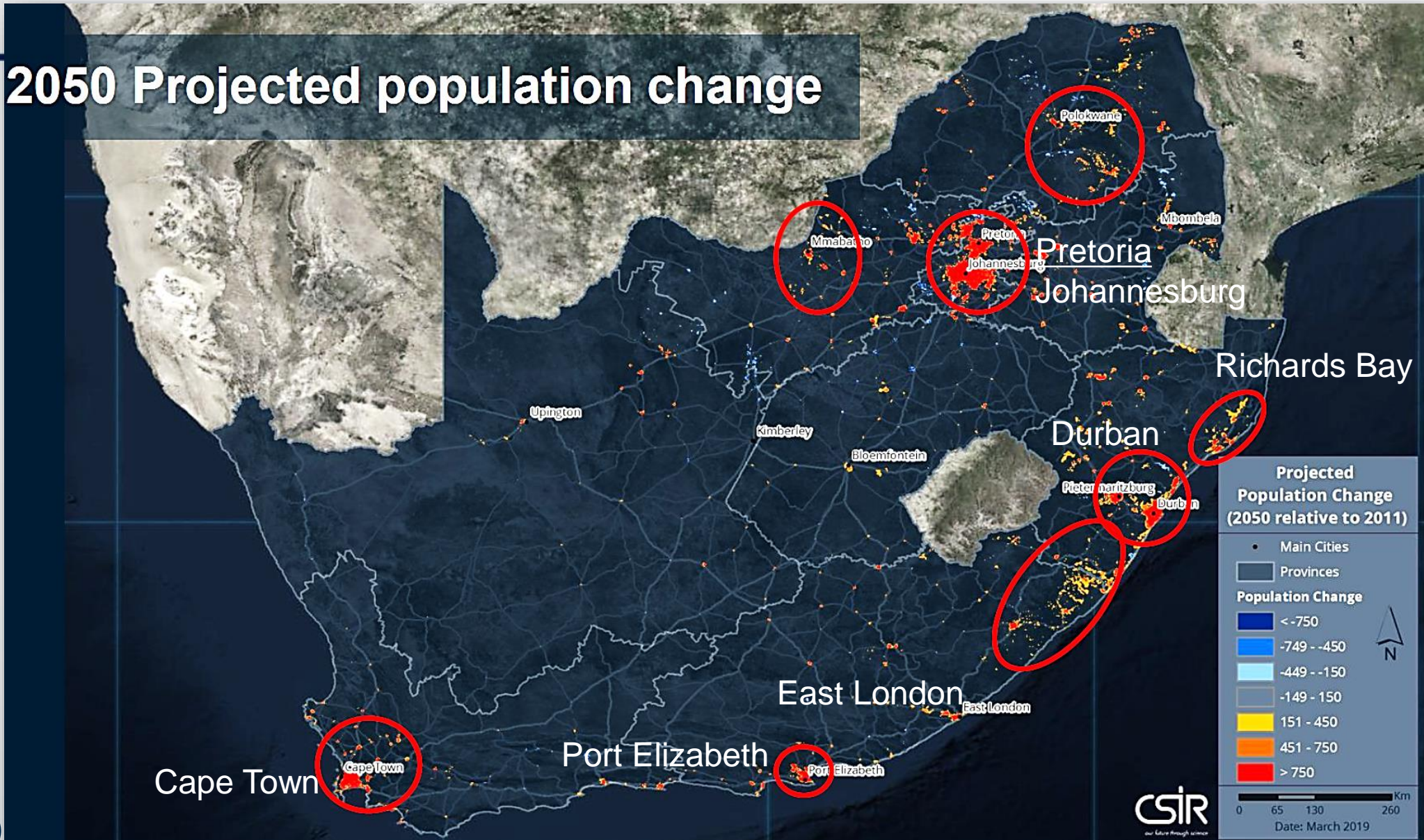
Richards Bay town & port

Population

- In South Africa, about **40%** of the population lives within 60 km of the ocean and

- in 2011 an estimated **3.5 million** South Africans resided within 5-7 km of a coastline, and

- **60%** of these people were in the four densely populated metropolitan areas.

- Populations in coastal municipalities **grew by approximately 1.8 million** people between 2001 and 2011, and this rate, which far exceeds national growth rates in other areas, continues to date.

→ **Resulting pressures on the coastal zone are high**

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Future Population

2050 Projected population change

Polokwane · Mbombela · Pretoria · Johannesburg · Richards Bay · Durban · Pietermaritzburg · East London · Port Elizabeth · Cape Town · Mmabatho · Upington · Kimberley · Bloemfontein

Projected Population Change (2050 relative to 2011)
- Main Cities
- Provinces

Population Change
- < -750
- -749 - -450
- -449 - -150
- -149 - 150
- 151 - 450
- 451 - 750
- > 750

Date: March 2019

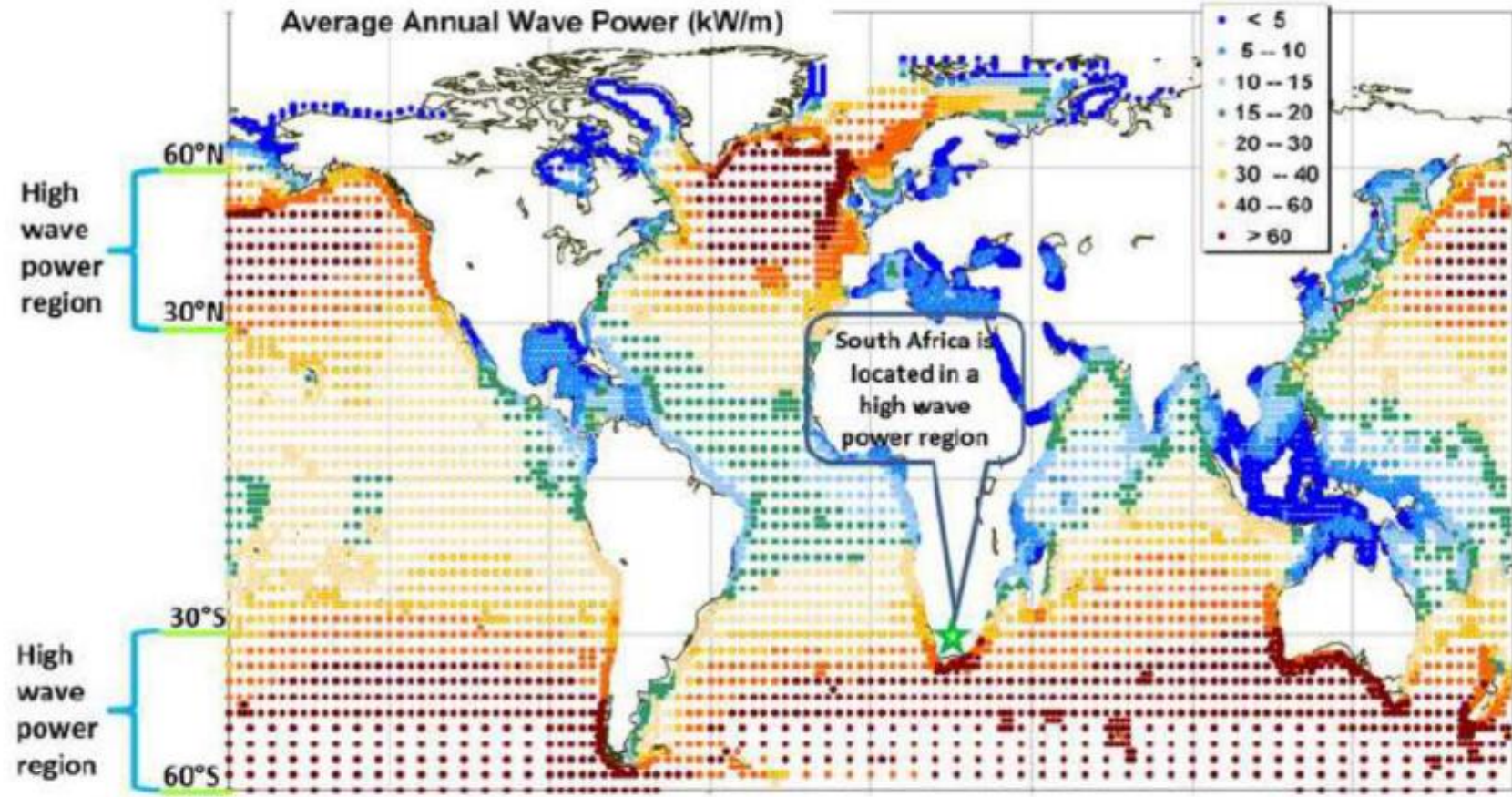# Coastal risk

Very high wave energy!

Figure 2-1: Global distribution of mean annual average wave power (kW/m) in deep water (Waves data/OCEANOR/ECMWF)

2007 KZN sea storm: erosion is not the problem!

The presence of infrastructure is.

Photos: D Phelp

Disastrous storms are common

Inclement Durban weather keeps SAMSA on its toes

Pretoria: 11 October 2017

The horrible wet and stormy weather that hit the port city of Durban in KwaZulu-Natal on Tuesday resulting in a massive flooding in parts of the city and causing chaos with shipping at the port, will continue to be monitored for its effects on sea traffic, the South African Maritime Safety Authority (SAMSA) has said.

In a media statement shared on social media early on Wednesday, SAMSA said after the breakout of the heavy downpour of rain and massive storm that led rapidly to some vessels at the port of Durban breaking loose and drifting dangerously, the organisation – jointly worked closely with the Transnet National Ports Authority (TNPA) round the clock to manage the chaotic situation.

Death toll from floods in South Africa's Durban rises to at least 341

MOGOMOTSI MAGOME
JOHANNESBURG
REUTERS
PUBLISHED APRIL 14, 2022

The destruction at Umdloti beach north of Durban in South Africa on April 14.
MARCO LONGARI/AFP/GETTY IMAGES

Between 1980 and 2010, over 77 disastrous flood events in KwaZulu-Natal province and others.

The flood events can be categorised as disastrous when lives are lost, people are displaced and property is destroyed.

Climate change in South Africa

→ even more storms in the future!
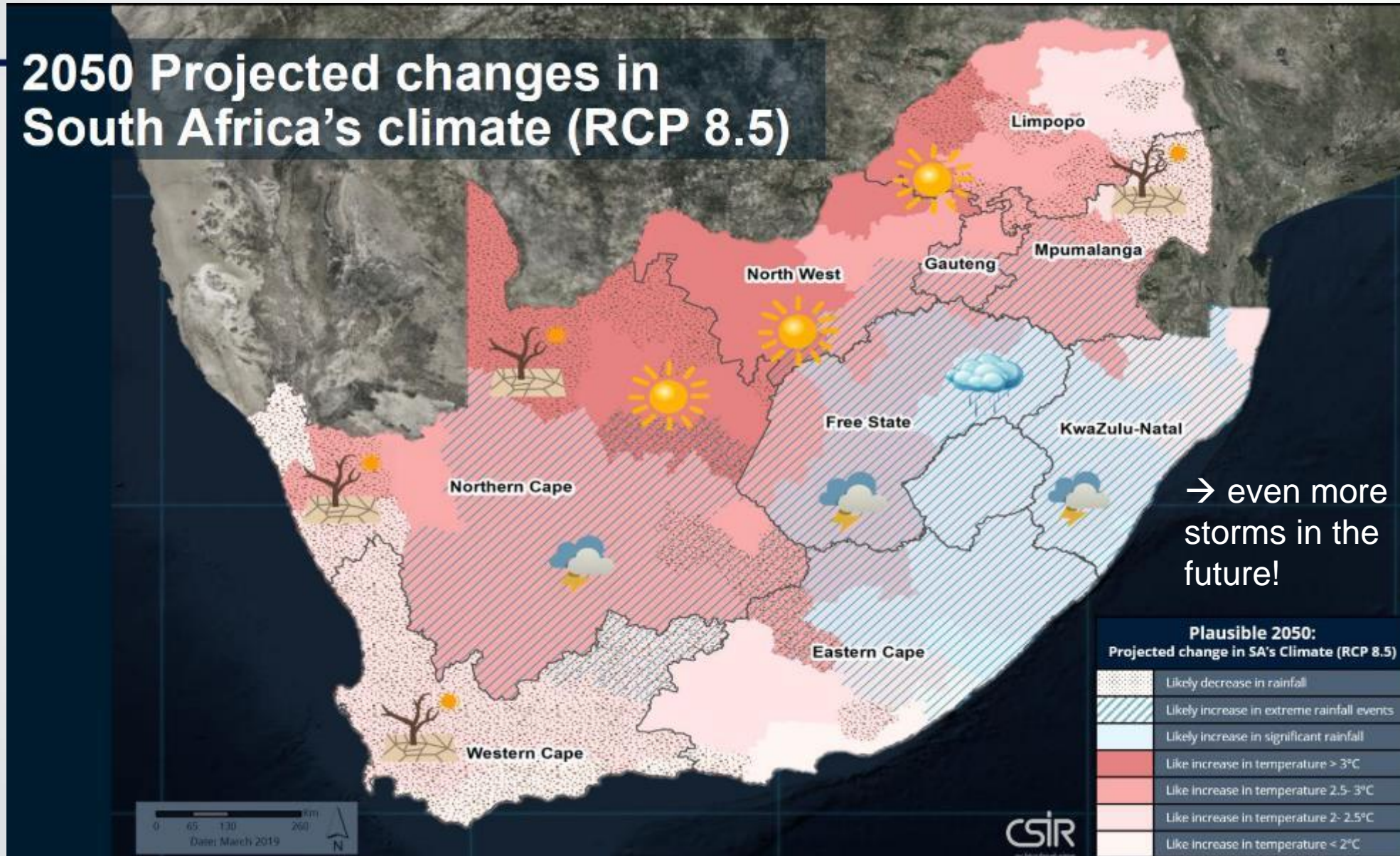
No. of Buildings in SA coastal flood risk zones

2011

Hazard risk	total	%	NC	WC	EC_urb	EC_trad	KZN_urb	KZN_trad
very high	15	0.002	2	13	-	-	-	-
high	738	0.1	102	585	33	4	14	-
medium	17 044	2.8	467	14 377	1 155	30	989	26
low	106 278	17.2	1 259	73 460	15 700	456	13 464	1 939
very low	494 308	79.9	1 476	353 103	52 343	758	58 116	28 512
TOTAL	618 383	100	3 306	441 538	69 231	1 248	72 583	30 477

2016

Hazard risk	TOTAL	%	NC	WC	EC_urb	EC_trad	KZN_urb	KZN_trad
Very high	55	0.01	1	52	1	-	1	-
high	1 158	0.1	100	983	60	4	11	-
medium	23 184	2.2	479	19 230	1 969	87	1 401	18
low	161 998	15.3	1 294	114 539	26 524	759	16 298	2 584
very low	873 550	82.4	1 511	655 959	103 347	1 466	69 435	41 832
TOTAL	1 059 945	100	3 385	790 763	131 901	2 316	87 146	44 434

2017

Flood risk	total	%	NC	WC	EC	KZN
5 - very high	66	0.01	2	61	2	1
4 - high	1 453	0.13	120	1 208	105	20
3 - medium	26 052	2.40	565	21 569	2 371	1 547
2 - low	170 097	15.67	1 351	119 825	28 928	19 993
1 - very low	888 016	81.79	1 702	663 433	107 211	115 670
Total No.	1 085 684	100	3 740	806 096	138 617	137 231
% national	100.00		0.34	74.25	12.77	12.64

Very high-risk zone

→ directly affected by SLR

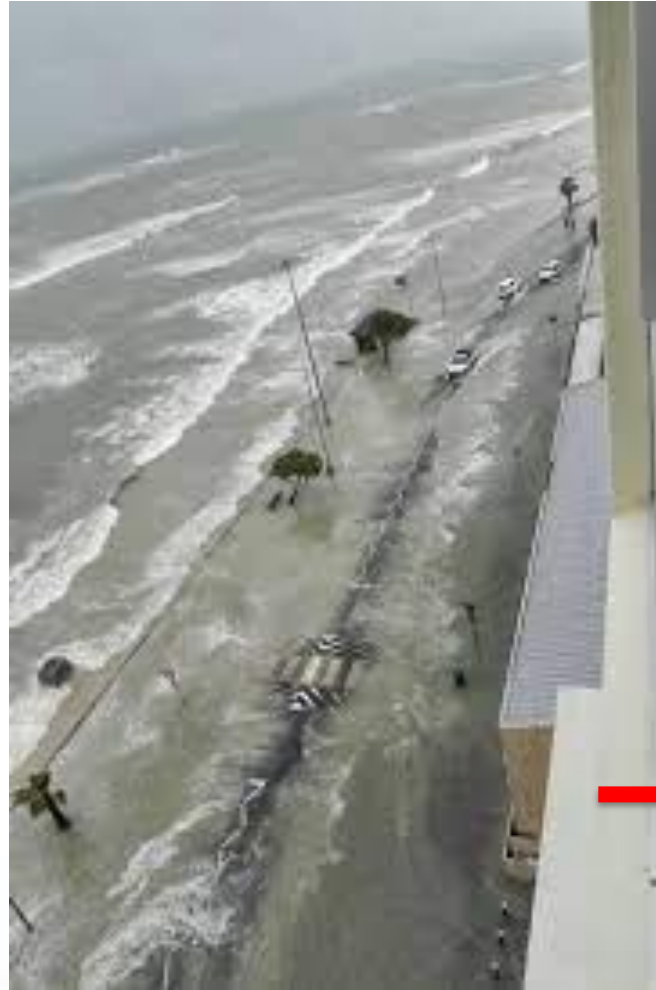(relatively few in international comparison, due to generally steep coasts)

Source: DFFE: National Coastal Assessment for South Africa, 2020.

Need for integrated coastal planning and climate change adaptation

- Engineered solutions

- **"working with nature" and embrace existing Green Coastal Infrastructure, i.e. vegetation**

Very expensive seawall construction (not feasible in many areas)

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Assessment of coastal vegetation intactness for coastal protection / climate change adaptation

Strandveld vegetation in northern False Bay, Cape Town

Only intact vegetation provides coastal protection

Detection of coastal dune vegetation degradation caused by illegal trespassing

→ Illegal pathways are starting points for dune erosion
→ RS detection allows targeted

→ Illegal pathways are starting points for dune erosion
→ RS detection allows targeted management response

Yellow: location of (mainly illegal) pathways through dunes
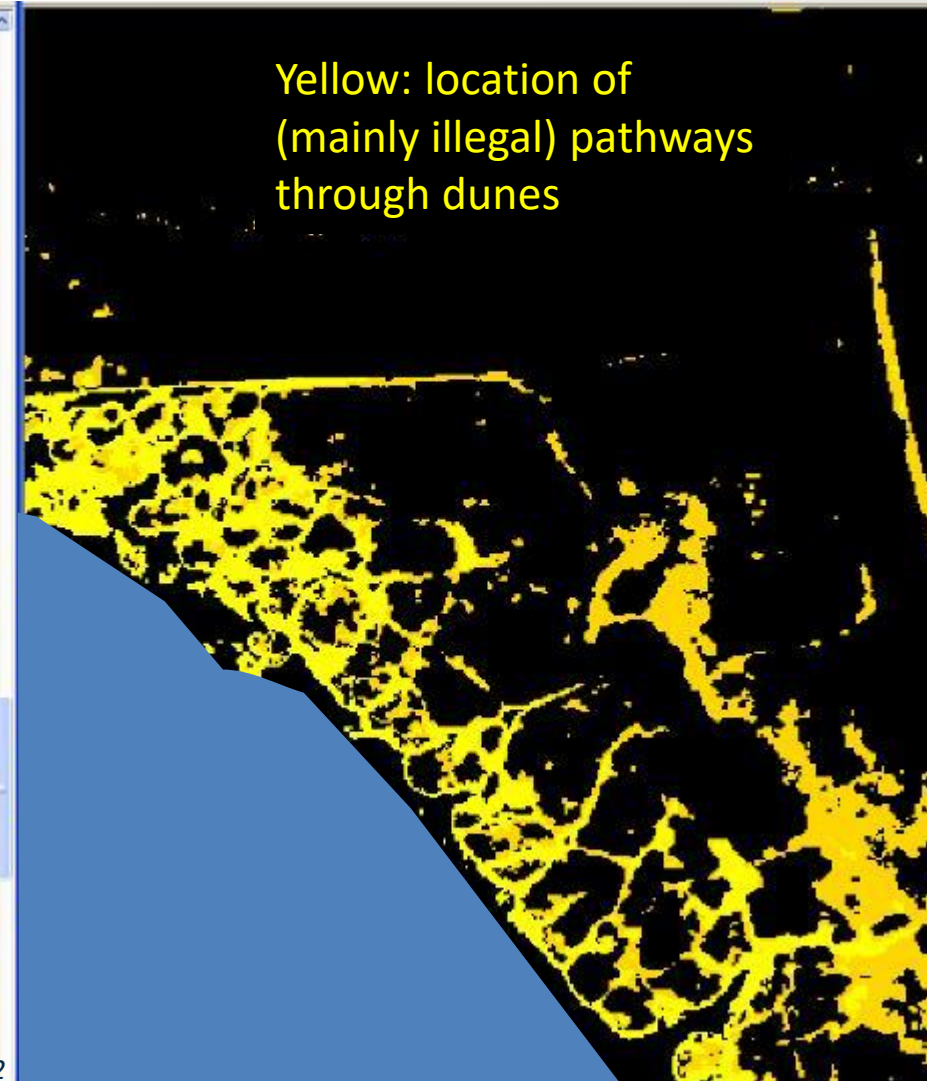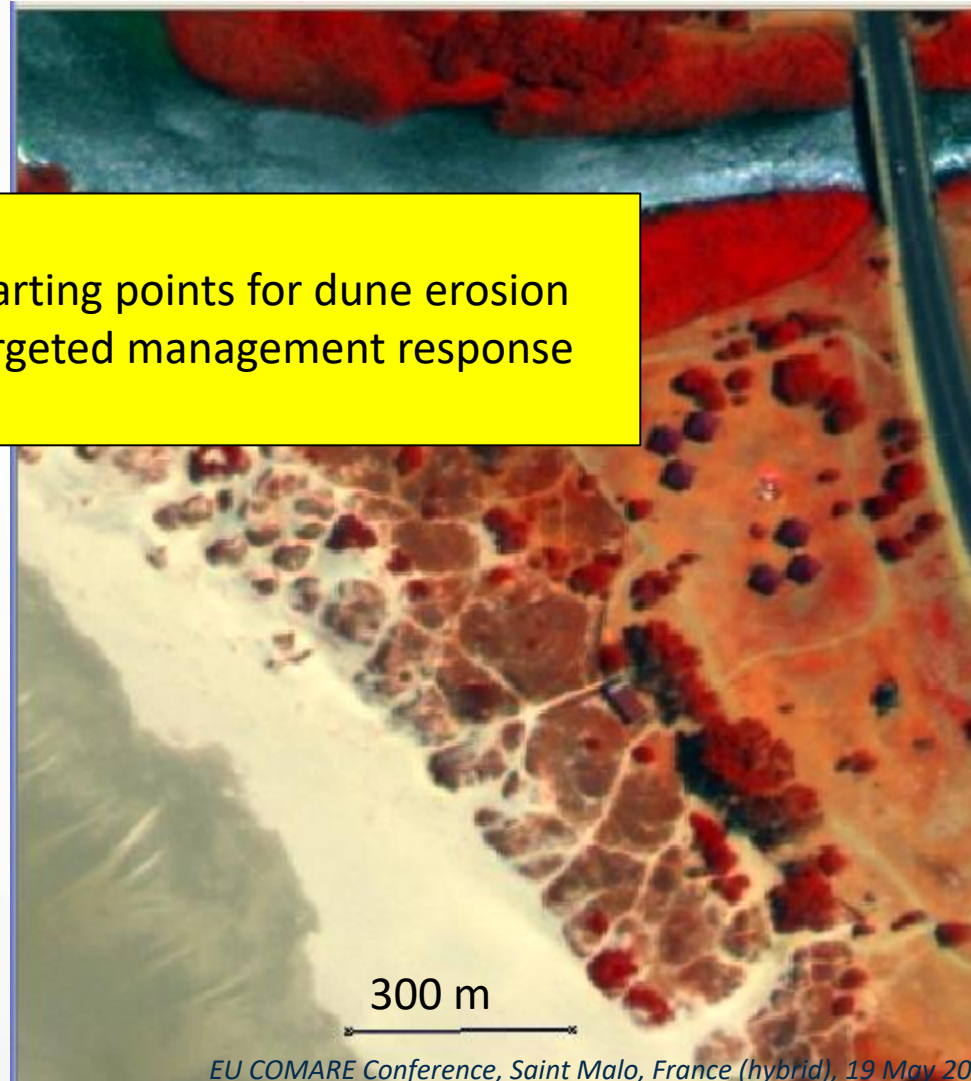
2m resolution WV-2 imagery 2014

300 m

13

Assessment of coastal Strandveld vegetation intactness
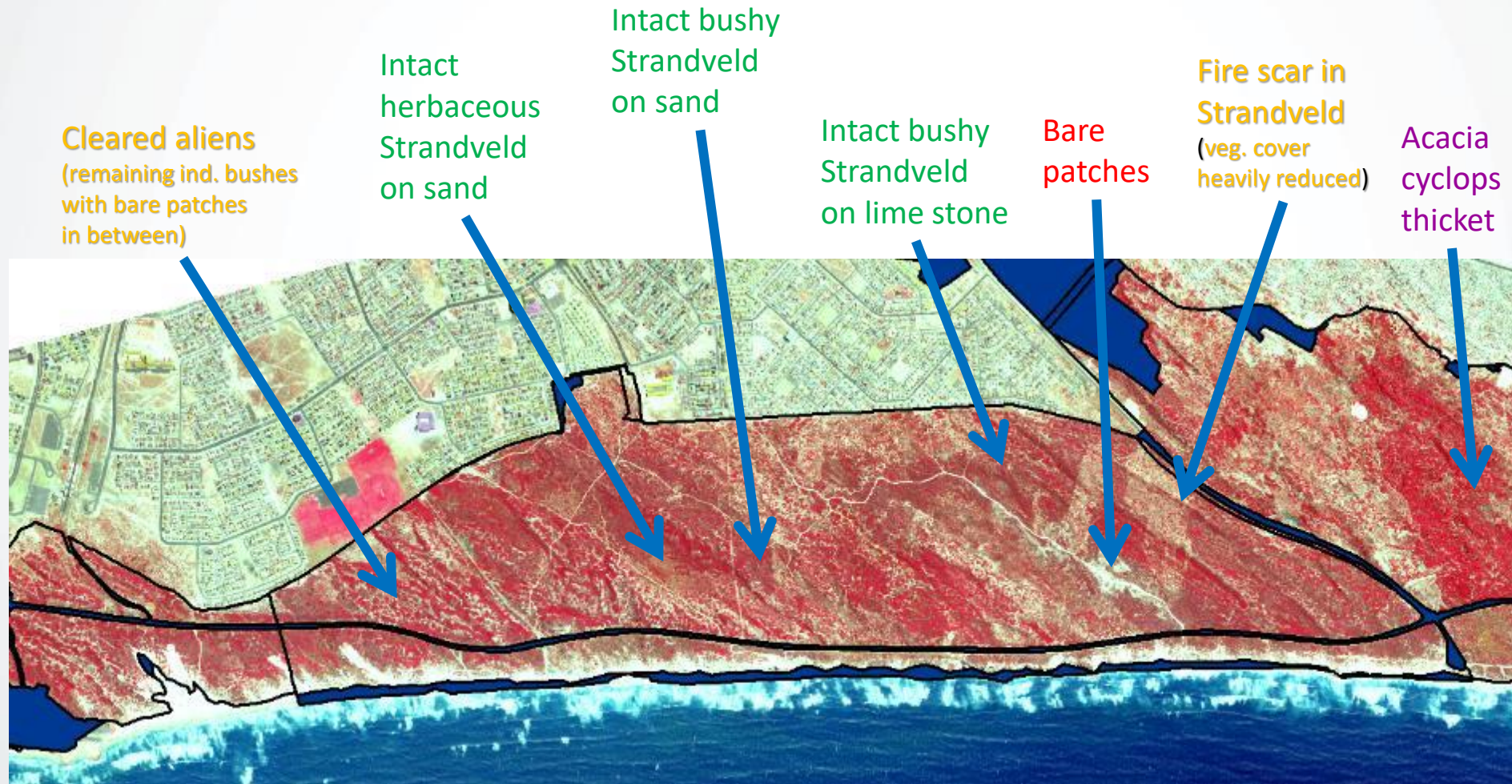
MSc thesis Cikizwa Mbolambi: "Assessment of Coastal Vegetation Degradation Using Remote Sensing in False Bay, South Africa". Department of Geography & Environmental Studies, Stellenbosch University, 2016

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Results for Feb 2014 image

Comparison with Oct 2014 image

Habitat Intacness Index Classes

- 🟥 1. Highly degraded
- 🟨 2. Moderately degraded
- 🟩 3. Lightly degraded
- 🟩 4. Intact vegetation
- 🟪 5. Alien vegetation

0   0.5   1   2   Kilometers

N

MSc thesis Cikizwa Mbolambi: "Assessment of Coastal Vegetation Degradation Using Remote Sensing in False Bay, South Africa". Department of Geography & Environmental Studies, Stellenbosch University, 2016

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Results are sensitive to seasonal effects
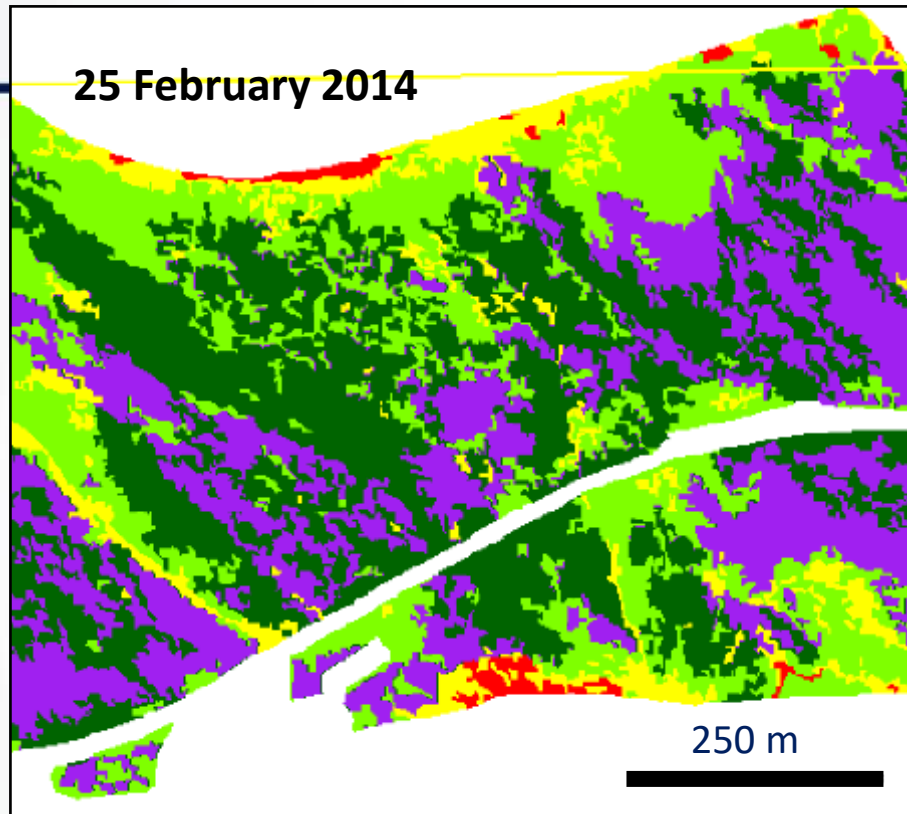
25 February 2014
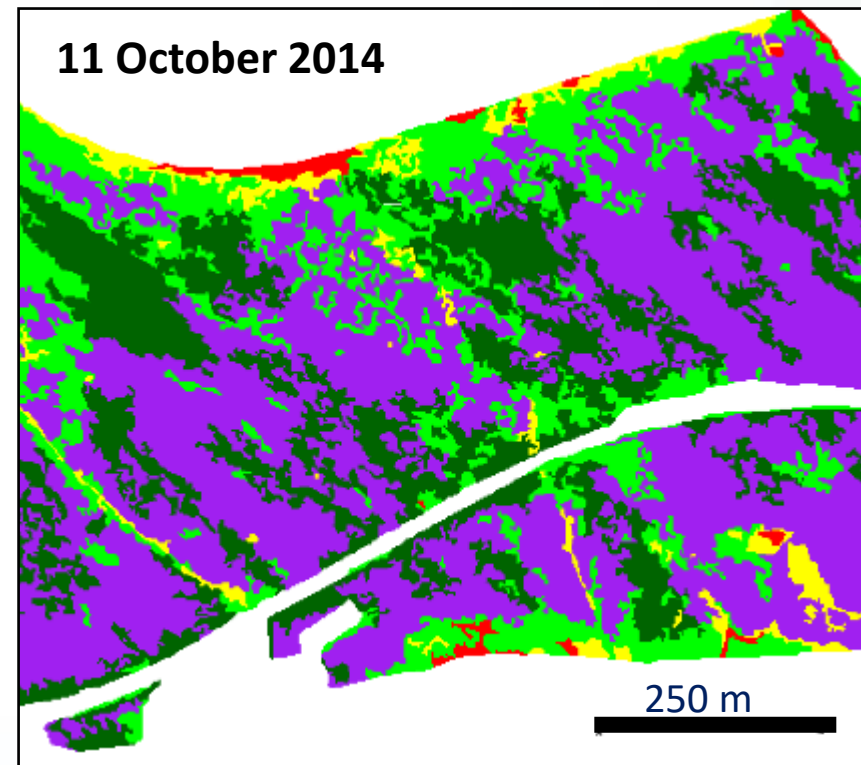
- **More sparse veg in Feb image**
  - → **Dry season effect**
- **Overestimation of aliens in wet Oct image**

11 October 2014

250 m

Habitat Intacness Index Classes

1. Highly degraded
2. Moderately degraded
3. Lightly degraded
4. Intact vegetation
5. Alien vegetation

N

250 m

MSc thesis Cikizwa Mbolambi: "Assessment of Coastal Vegetation Degradation Using Remote Sensing in False Bay, South Africa", Department of Geography & Environmental Studies, Stellenbosch University, 2016

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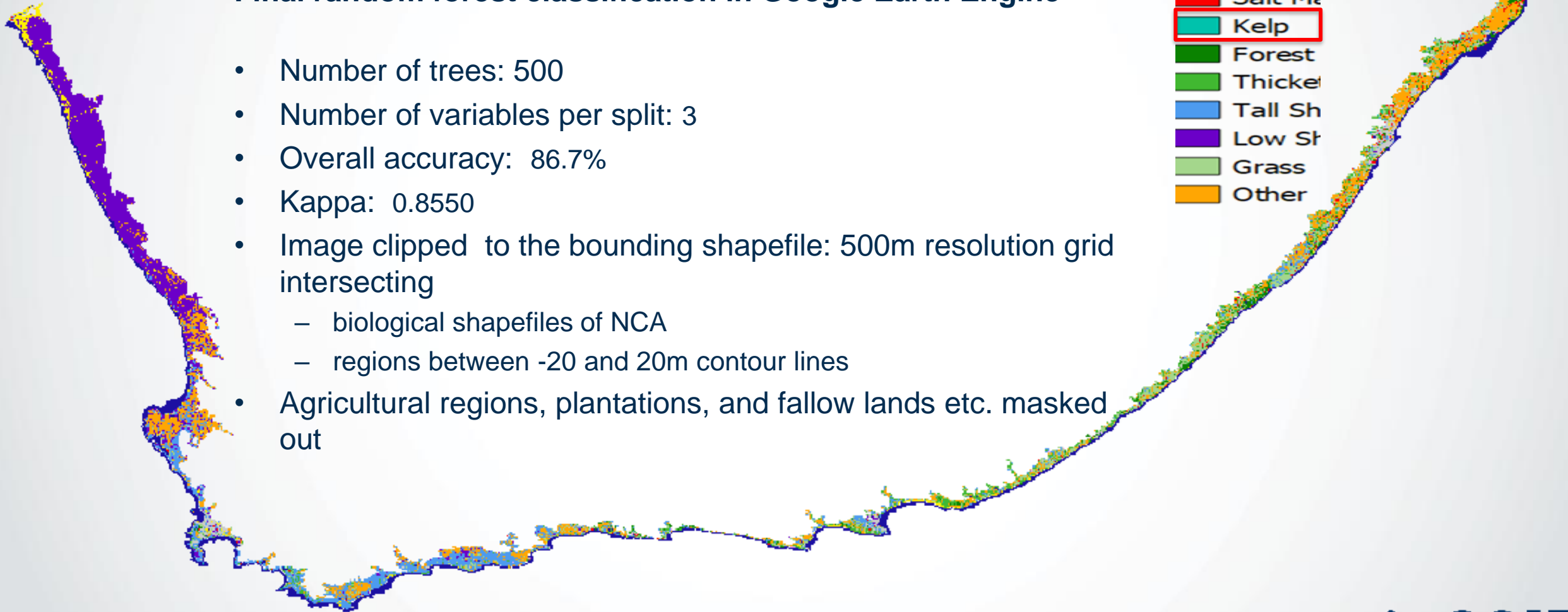# Coastal Ecosystem Mapping for South Africa
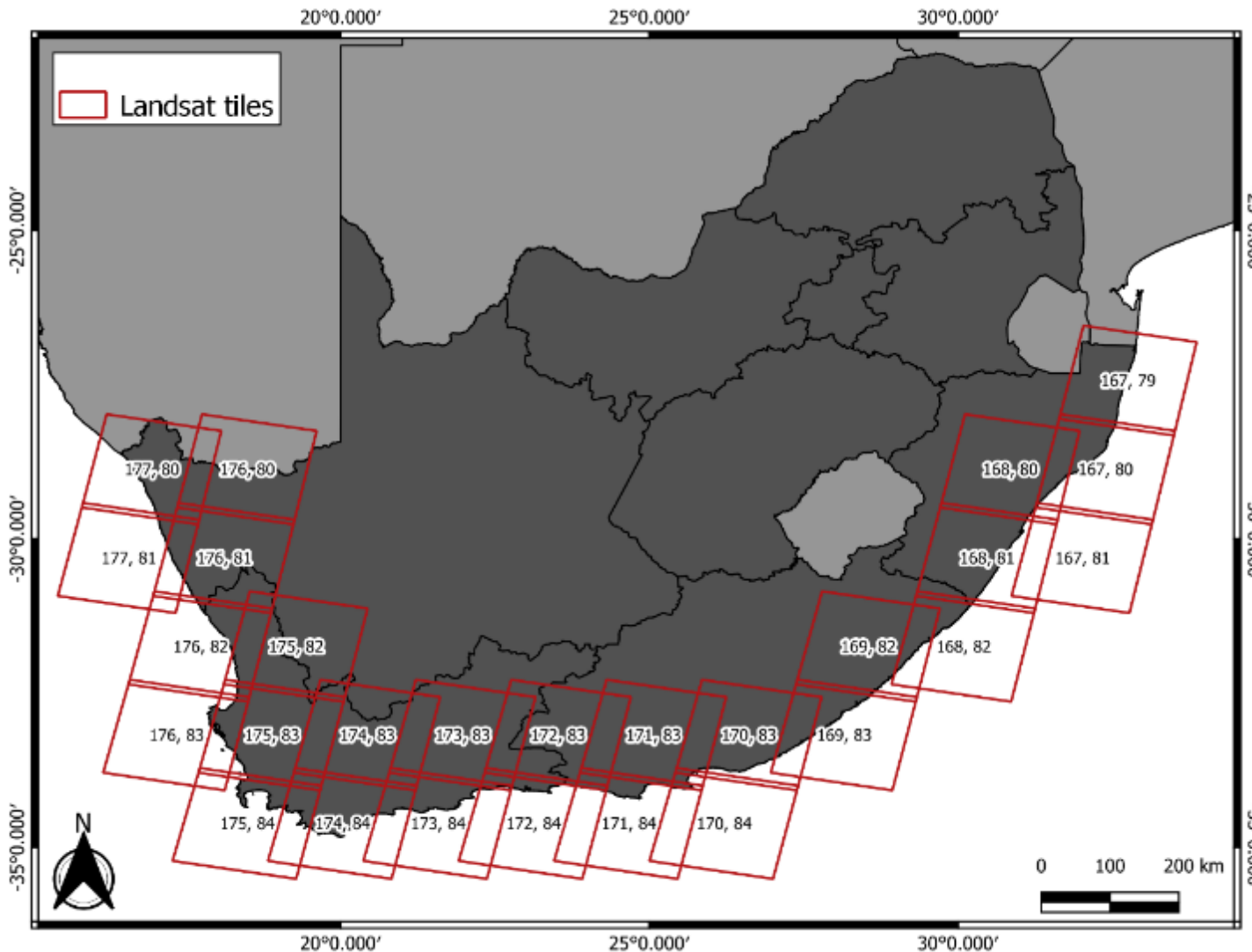
- **Google Earth Engine**

- **522 Landsat 8 ToA images**
  - 1 January 2018 - 31 December 2019
  - < 20% Cloud coverage
- Reduced to one Median image
  - Minimize clouds and shadow
  - Reduce noise

- **Random Forest Classification**

PhD Thesis Mariel Bessinger: "An Integrated Coastal Map of South Africa". Department of Geography & Environmental Studies, Stellenbosch University (ongoing)
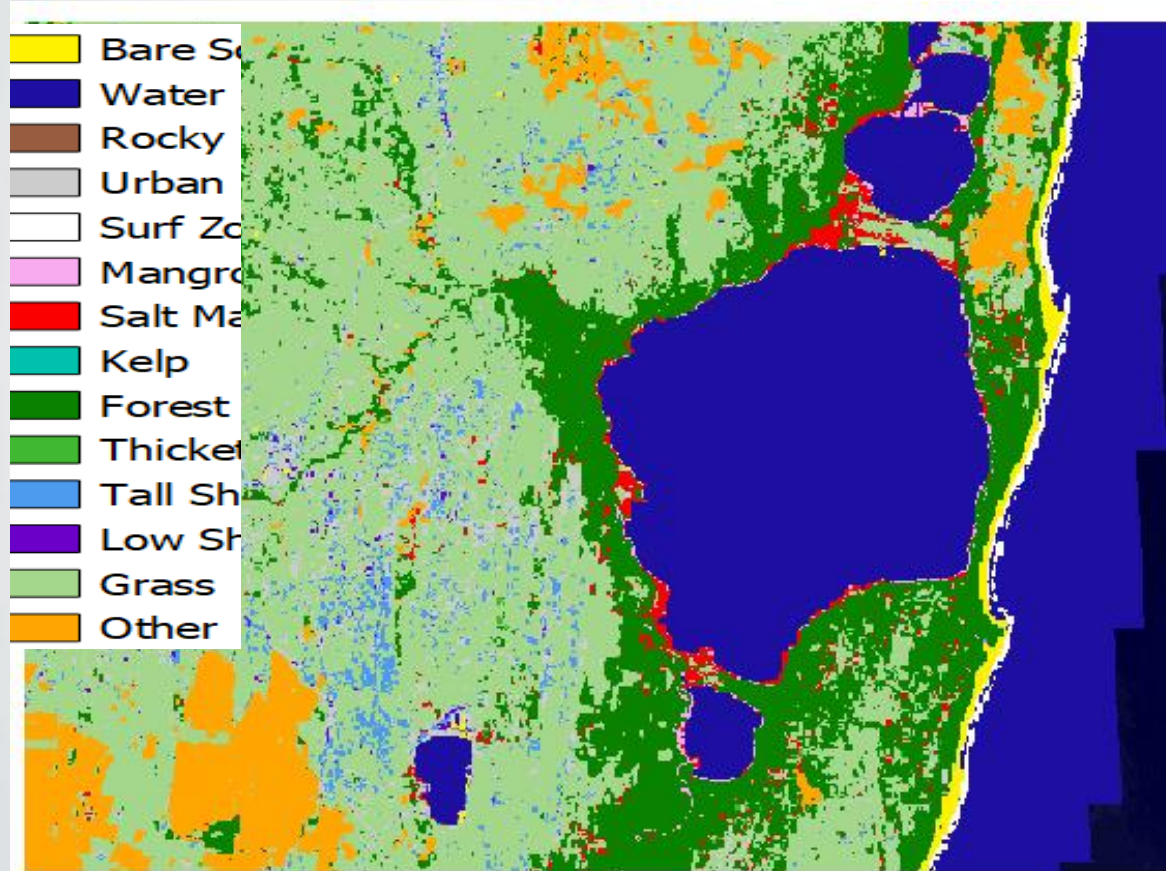
Coastal Ecosystem Mapping for South Africa

Final random forest classification in Google Earth Engine

- Number of trees: 500

- Number of variables per split: 3

- Overall accuracy: 86.7%

- Kappa: 0.8550

- Image clipped to the bounding shapefile: 500m resolution grid intersecting
  - biological shapefiles of NCA
  - regions between -20 and 20m contour lines

- Agricultural regions, plantations, and fallow lands etc. masked out

Legend:
- Bare S...
- Water
- Rocky
- Urban
- Surf Z...
- Mangr...
- Salt Ma...
- Kelp
- Forest
- Thicket
- Tall Sh...
- Low Sh...
- Grass
- Other

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S-2 Vegetation Mapping Results

Lakes - iSimangaliso Wetland Park

Legend:
- Bare So...
- Water
- Rocky
- Urban
- Surf Zo...
- Mangro...
- Salt Ma...
- Kelp
- Forest
- Thicket
- Tall Sh...
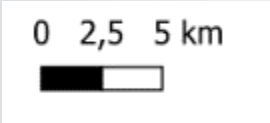- Low Sh...
- Grass
- Other

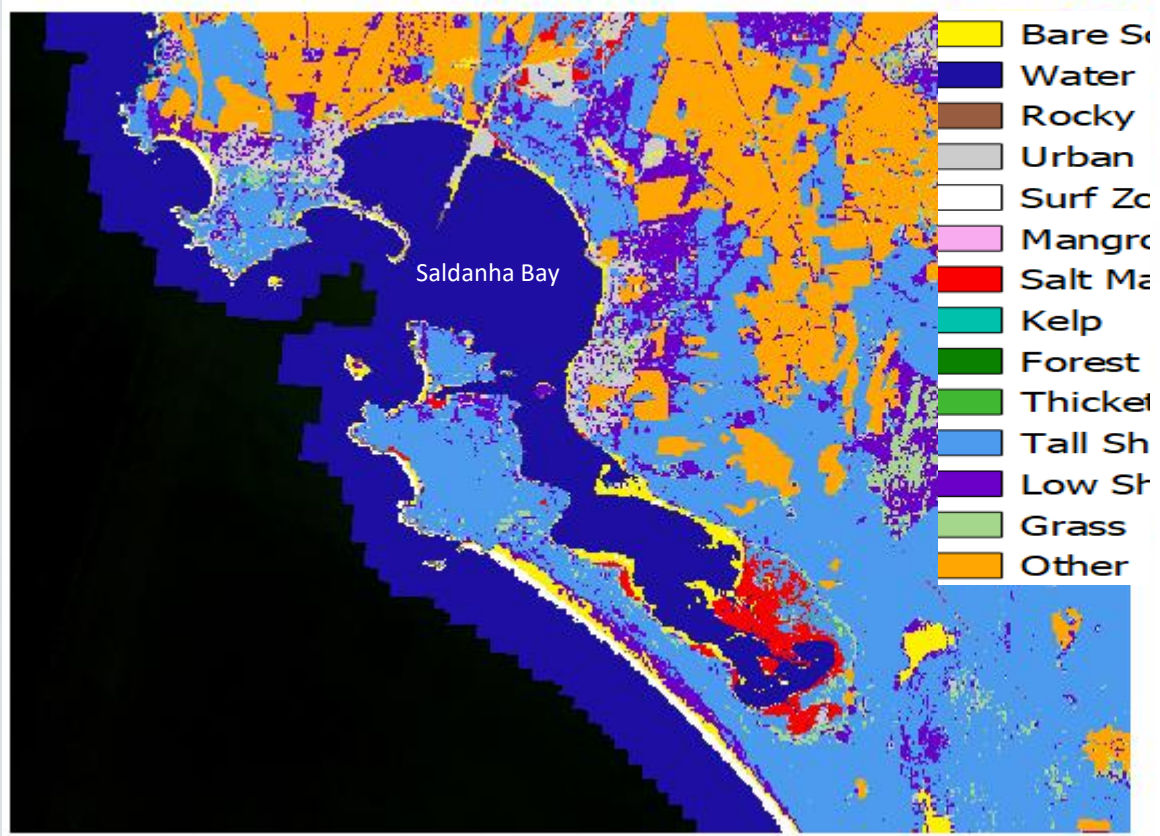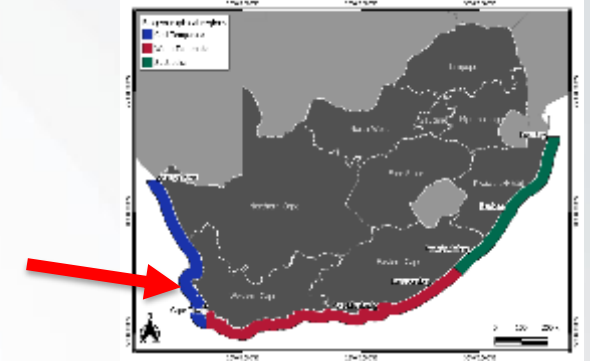0 1 2 km

PhD Thesis Mariel Bessinger, Department of Geography & Environmental Studies, Stellenbosch University

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S-2 Vegetation Mapping Results

Saldanha Bay/ Langebaan Lagoon

Legend:
- Bare So
- Water
- Rocky
- Urban
- Surf Zo
- Mangro
- Salt Ma
- Kelp
- Forest
- Thicket
- Tall Sh
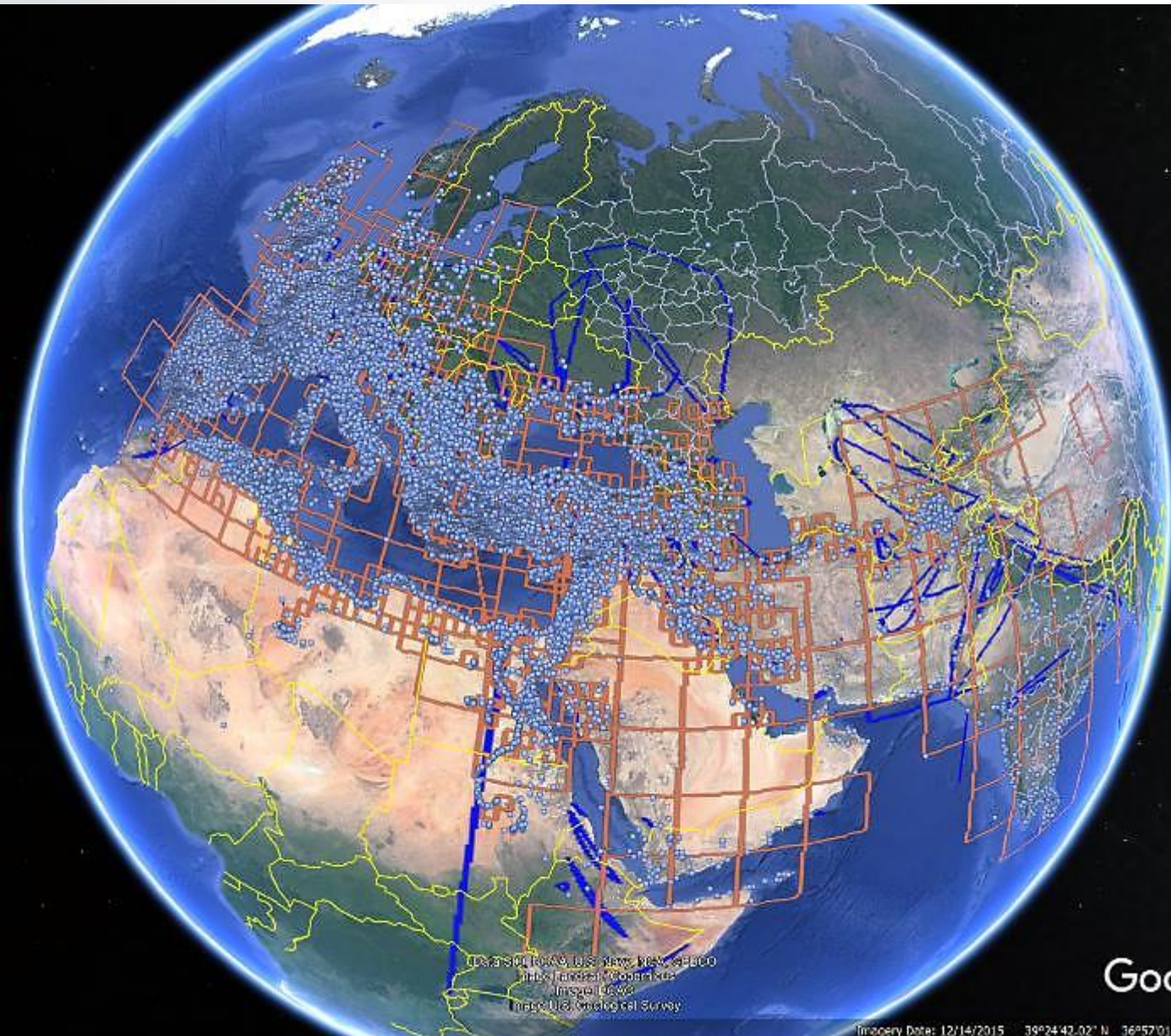- Low Sh
- Grass
- Other

Saldanha Bay

0 2,5 5 km

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User's and Producer's accuracy: >70% throughout – on a national scale!

	Bare Soil	Water	Rocky	Urban	Surf Zone	Mangroves	Salt Marshes	Kelp	Forest	Thicket	Tall Shrubs	Low Shrubs	Herbaceous
Producer's accuracy	93.55	96.67	92.50	78.67	98.13	85.33	80.00	99.33	88.00	70.56	80.67	91.25	78.57
User's accuracy	92.65	95.08	90.80	84.29	98.74	87.07	81.01	99.33	85.85	74.27	73.11	92.41	81.28

PhD Thesis Mariel Bessinger: "An Integrated Coastal Map of South Africa". Department of Geography & Environmental Studies, Stellenbosch University (ongoing)

Choice of RS data: usually a cost/resolution trade-off

e.g.: freely available Pleiades data

← Coverage for the northern Hemisphere

Source: https://pleiades.stoa.org/

Choice of RS data: usually a cost/resolution trade-off
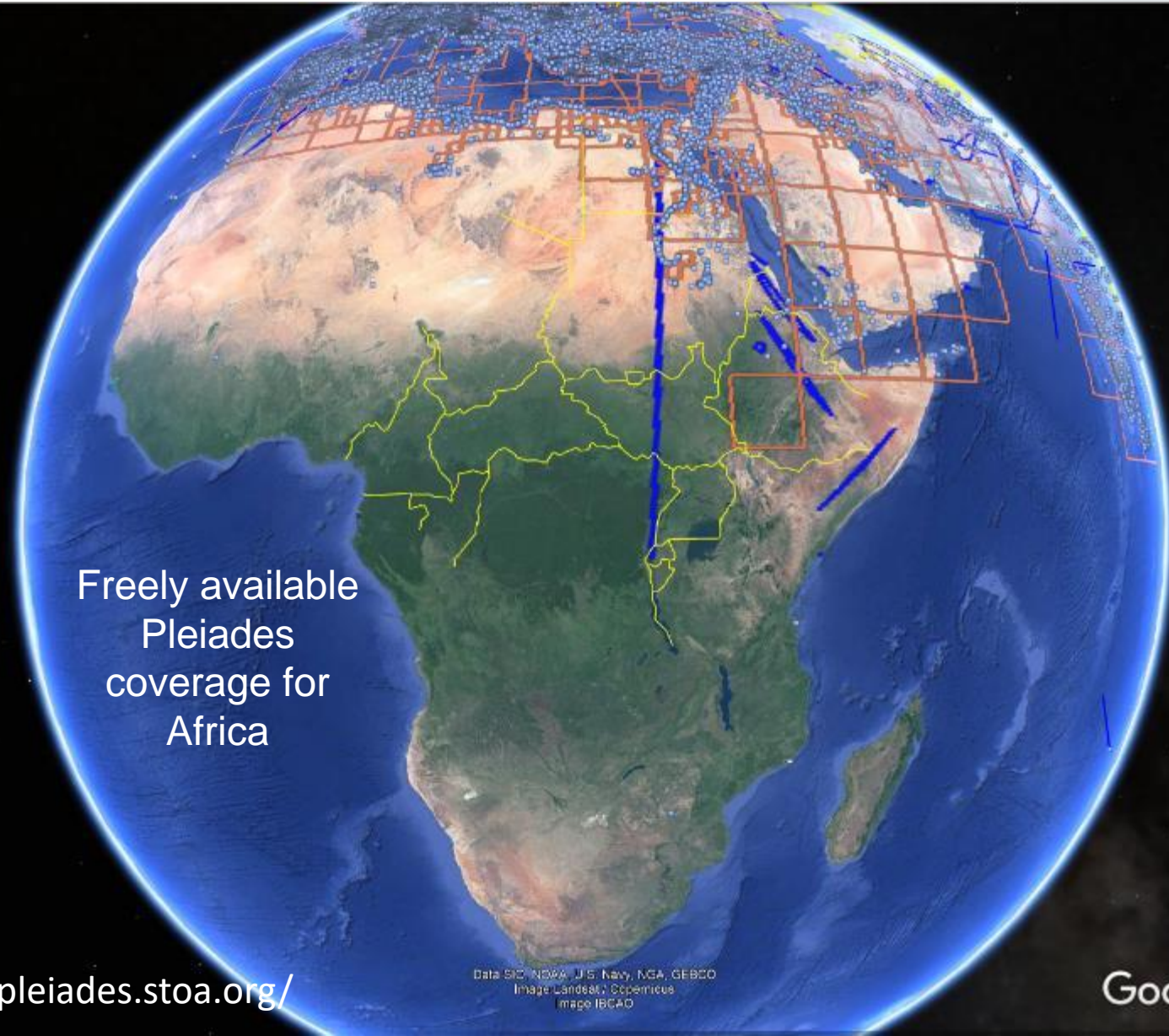
Freely available Pleiades coverage for Africa

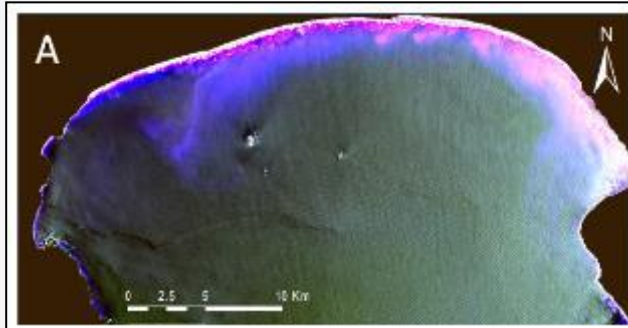Source: https://pleiades.stoa.org/

Bathymetry from Landsat imagery

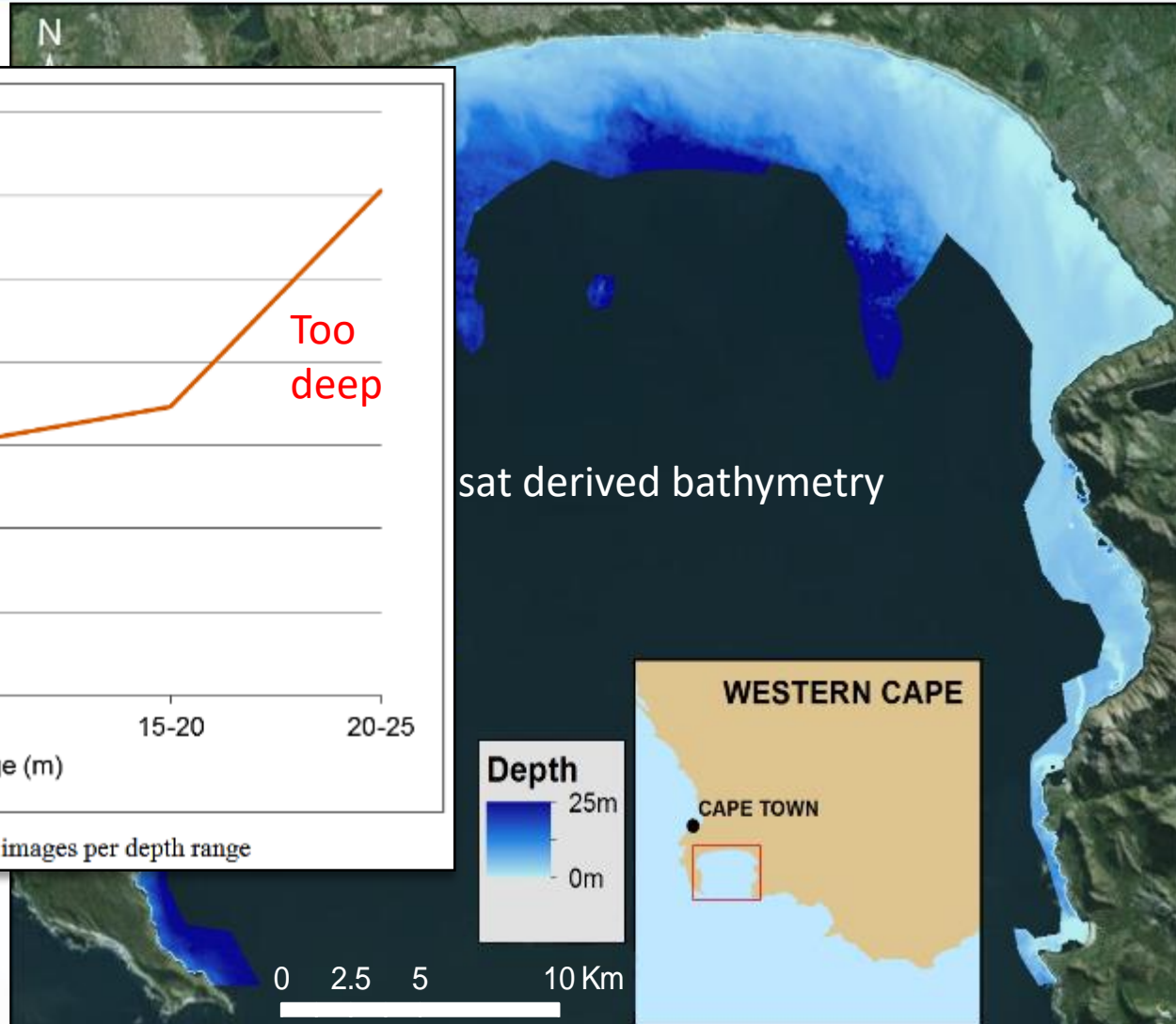Landsat 8 image for False Bay

Image corrected for Sun glint

Landsat derived bathymetry

BSc Hons thesis Michael Johnson 2015
Dep. of Geography and Environm. Studies
Stellenbosch University

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Bathymetry from Landsat imagery

Landsat 8 image for False Bay

Figure 4.3: Average RMSE (m) for all the False Bay images per depth range

...sat derived bathymetry

BSc Hons thesis Michael Johnson 2015
Dep. of Geography and Environm. Studies
Stellenbosch University

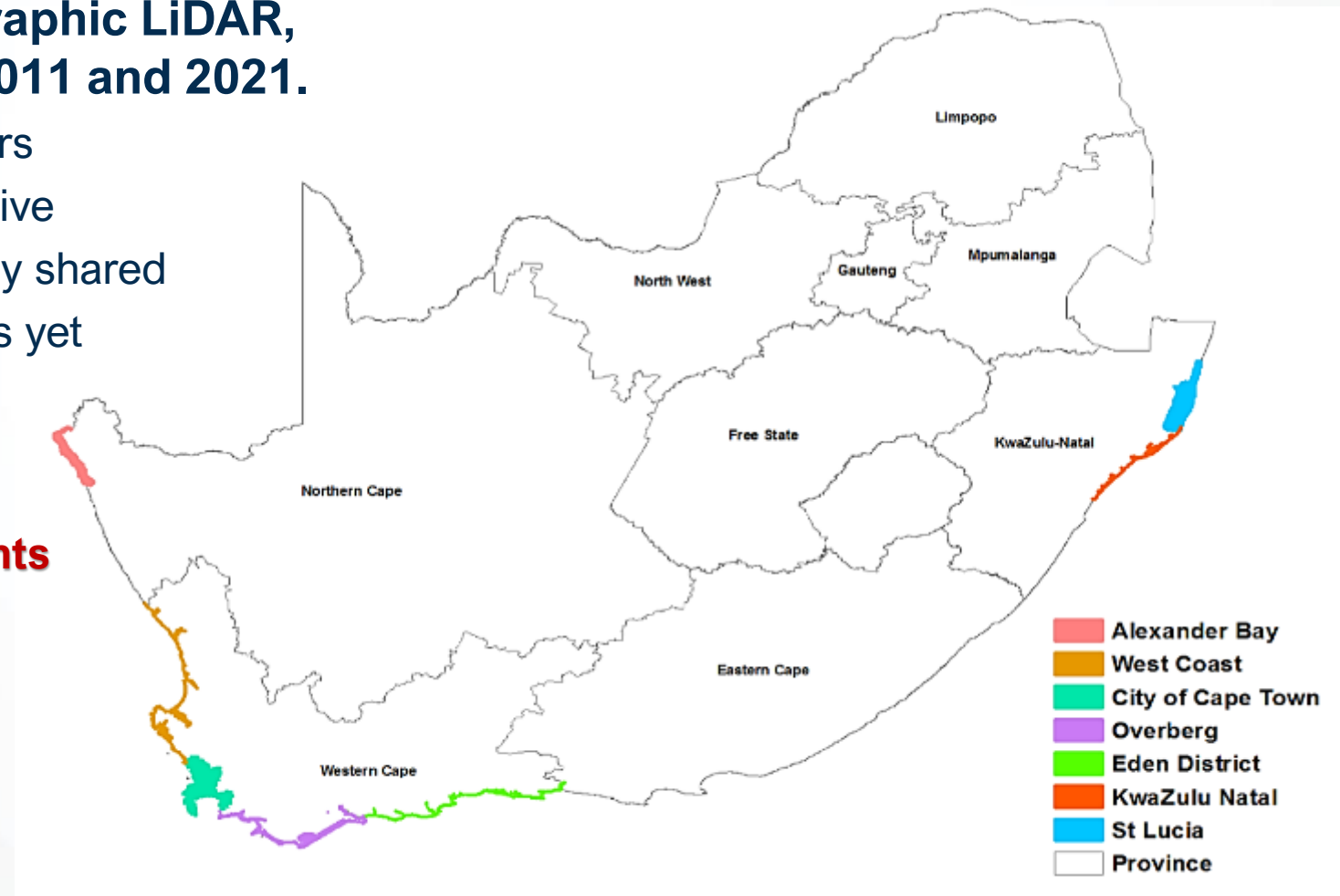# Strong upwelling makes RS bathy assessment difficult
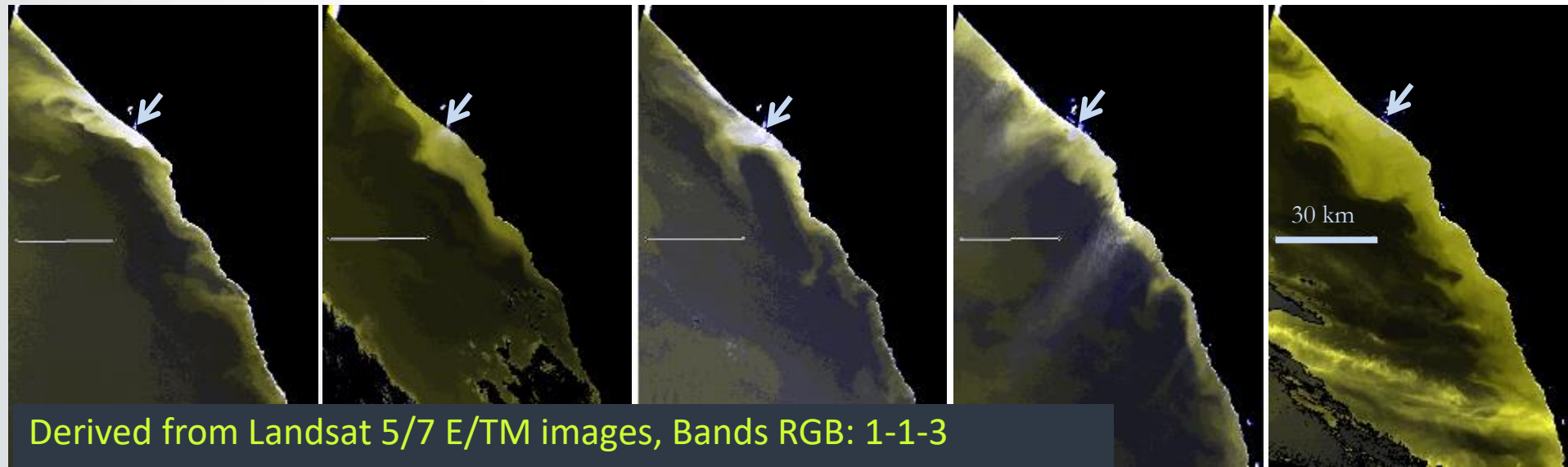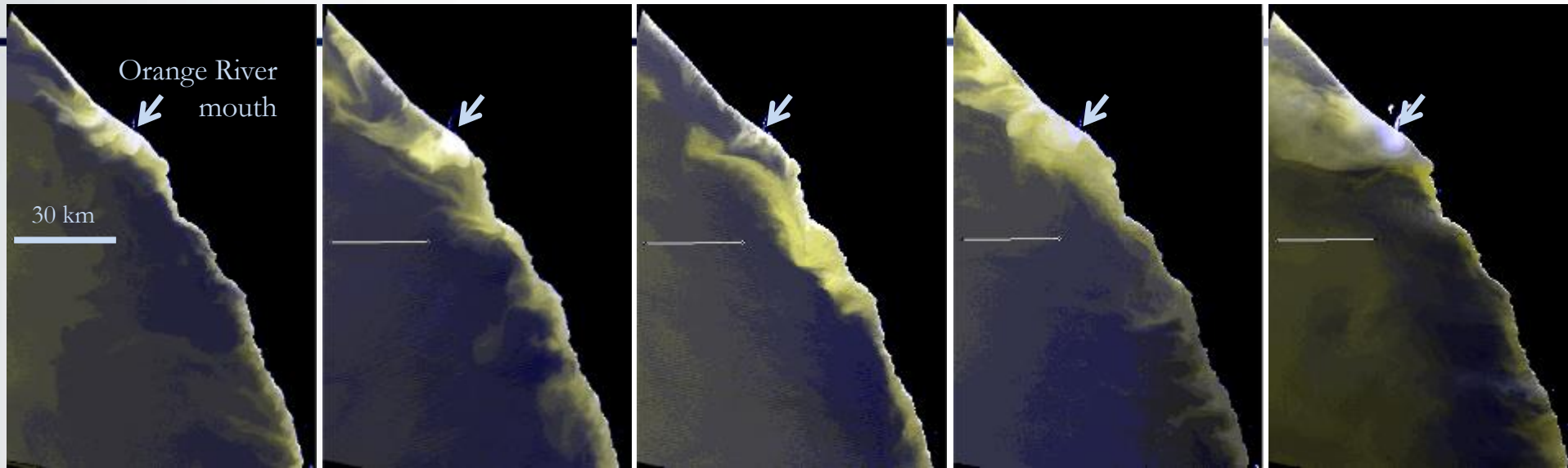
Derived from Landsat 5/7 E/TM images, Bands RGB: 1-1-3

Lidar coverage

- **To date, about 50% of SA's coast are covered with topographic LiDAR, acquired between 2011 and 2021.**
- Very few LiDAR providers
- Acquisitions are expensive
- LiDAR data are not freely shared
- No national custodian as yet

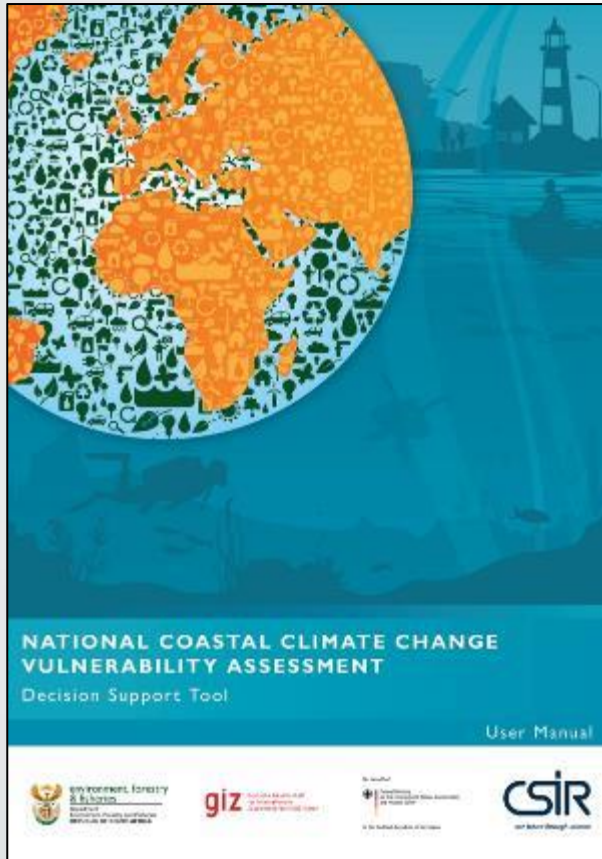**→ Limits coastal risk and environmental assessments**

Alexander Bay
West Coast
City of Cape Town
Overberg
Eden District
KwaZulu Natal
St Lucia
Province

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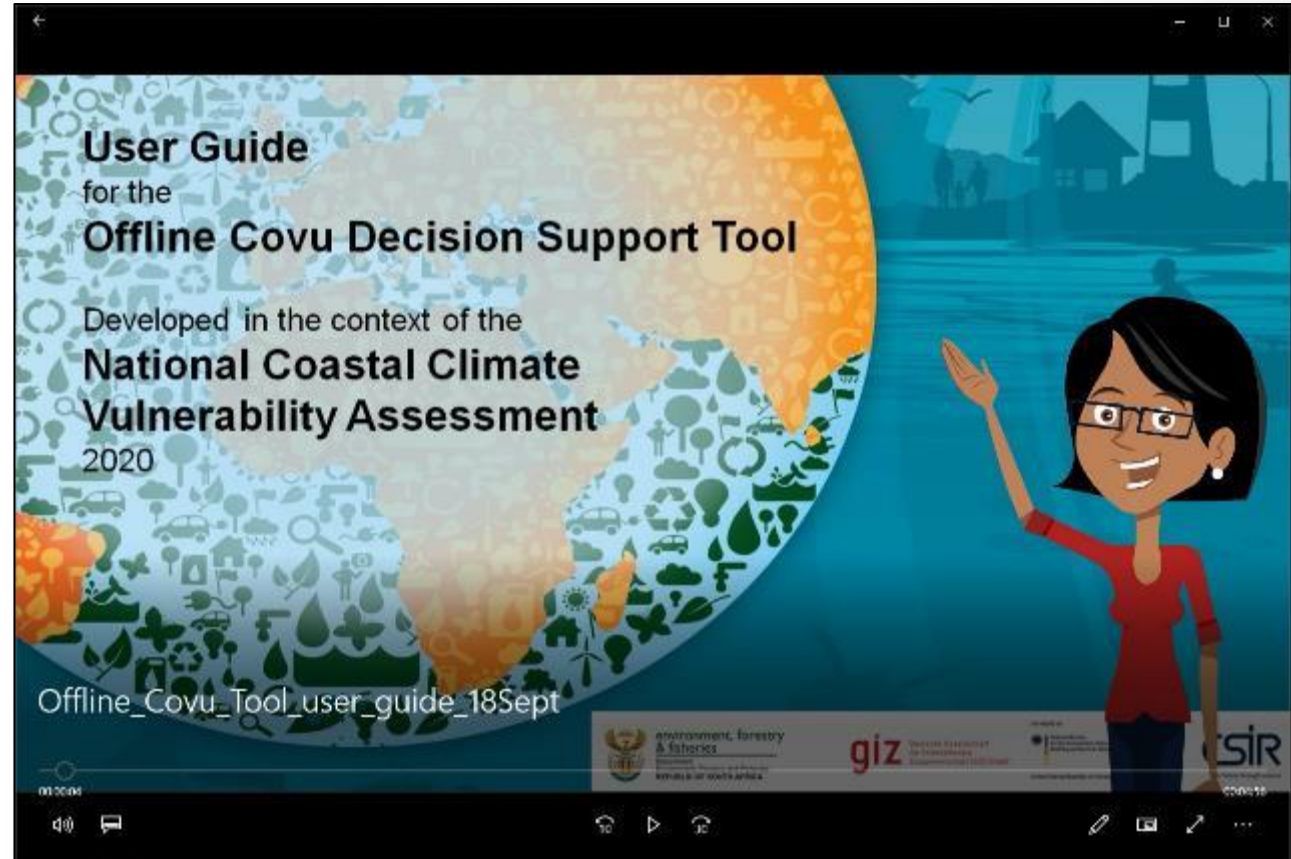# National Coastal Climate Change Vulnerability Assessment (2019-2010)

1. To **develop a geospatial index** for the vulnerability of SA's coasts in terms of climate change impacts. These are impacts primarily associated with flooding (through storm surge, wave runup and sea level rise) and shoreline erosion;

2. To **develop an interactive decision support tool (DeST)** that allows the users, primarily government officials in all spheres of government, to view and assess the various aspects of coastal risk and use of the spatially explicit information for spatial planning and climate change adaptation, and

3. **To integrate that DeST with existing tools or platforms**

4. **To capacitate government officials to use these tools.**

• **→ Respond to the urgent need for a National Coastal Spatial Vulnerability Index** to inform coastal spatial management in response to the national climate change adaptation strategy**.**

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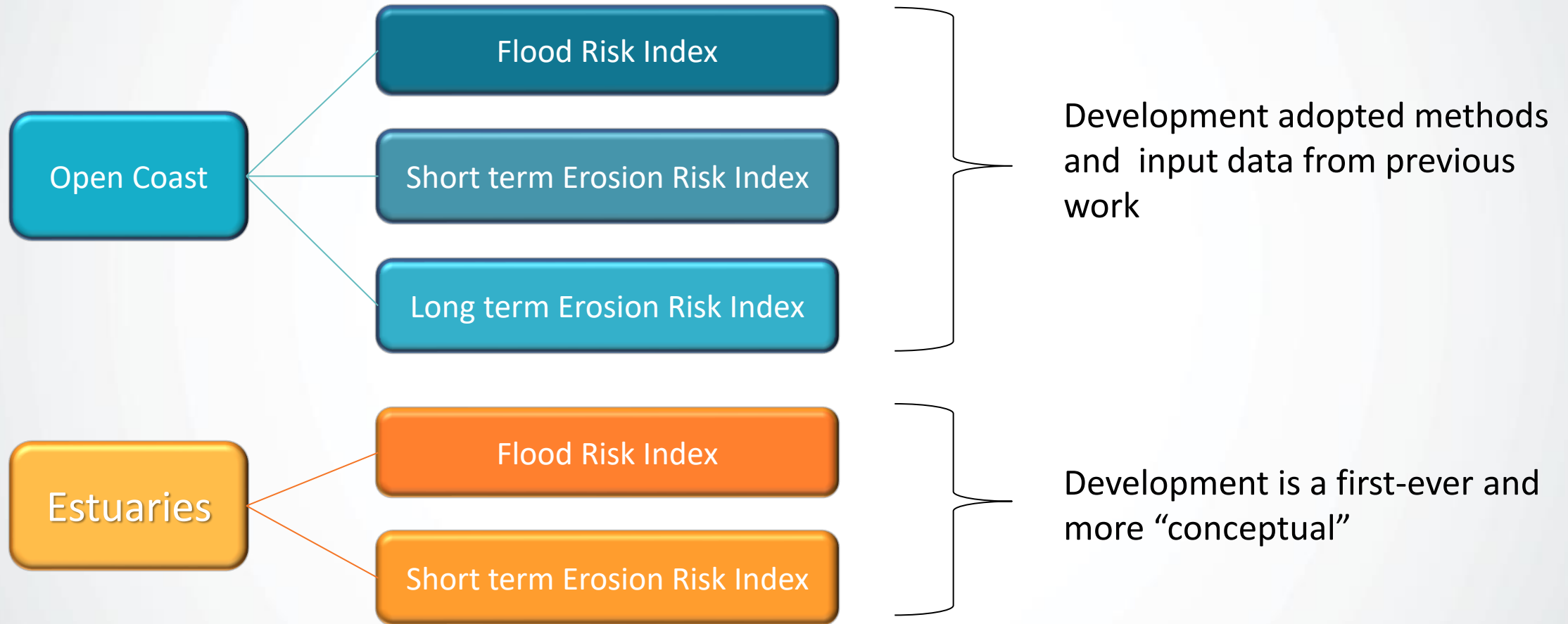# National Coastal Climate Change Vulnerability Assessment: Outputs
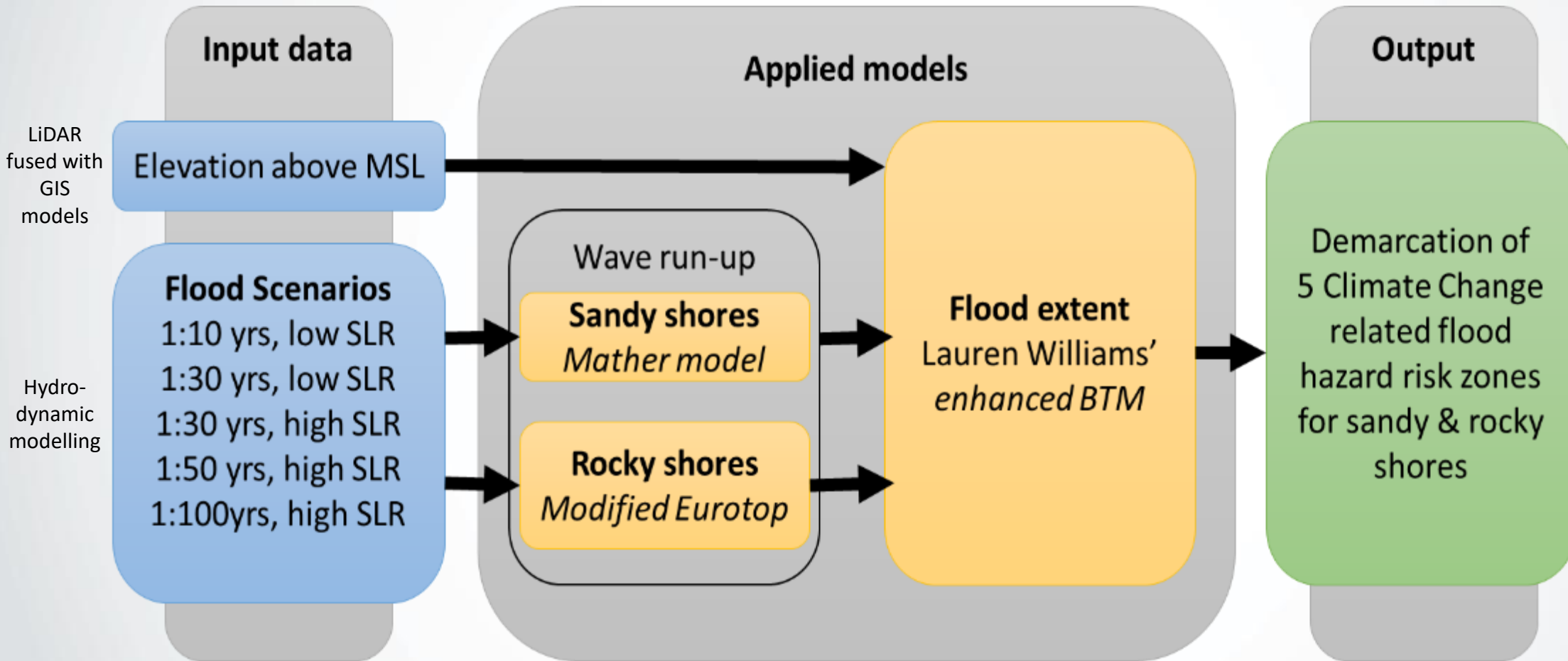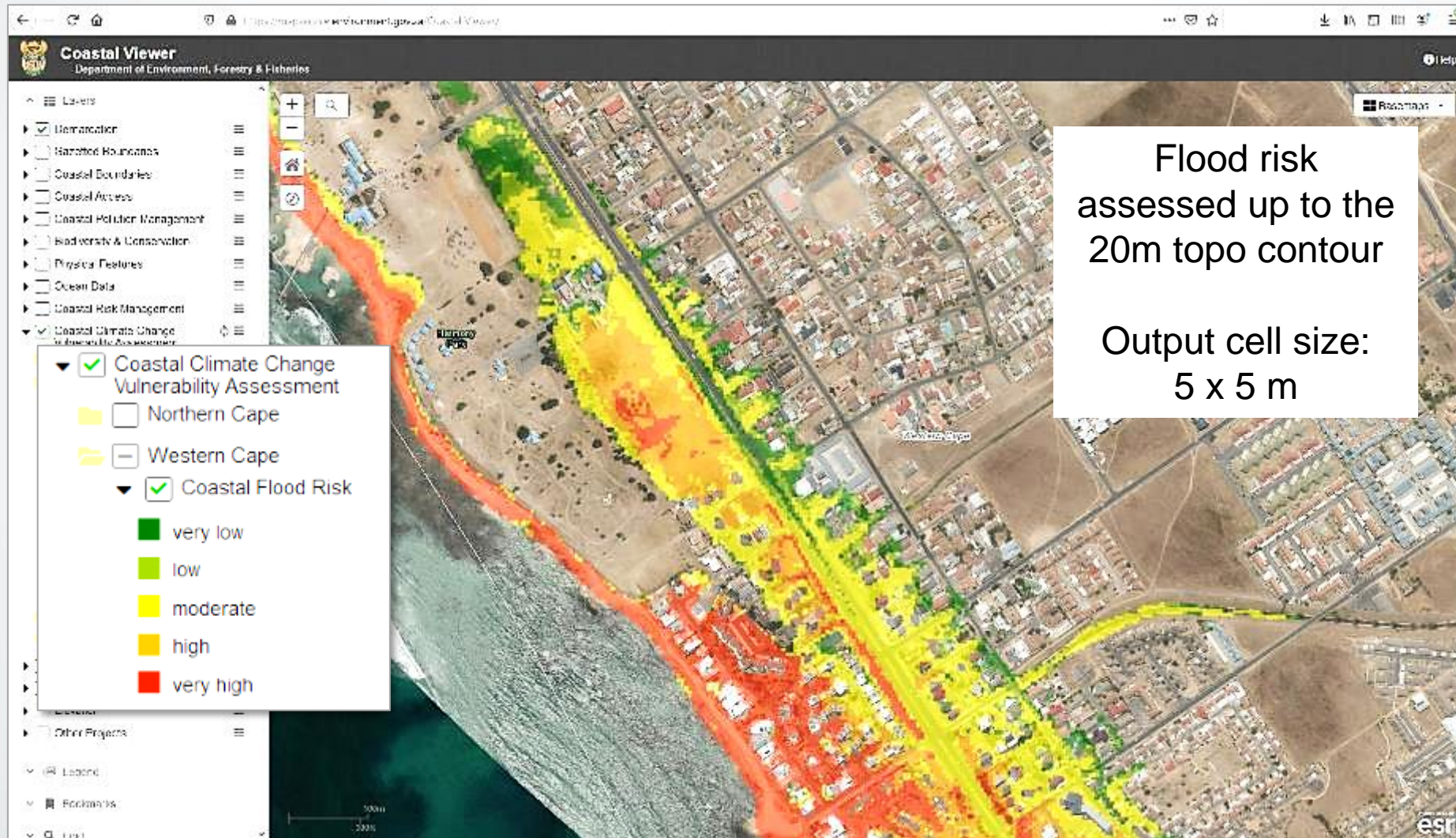

PDF version

5 minutes video instruction

Overview: https://www.youtube.com/watch?v=14CBEQgcpes

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Coastal Risk Assessment Components

Open Coast
- Flood Risk Index
- Short term Erosion Risk Index
- Long term Erosion Risk Index

Development adopted methods and input data from previous work

Estuaries
- Flood Risk Index
- Short term Erosion Risk Index

Development is a first-ever and more "conceptual"

Open Coast Flood Risk Index

PhD Lauren Lyn Williams 2020: "A risk assessment in relation inundation in South Africa's coastal zone as a result of extreme high water events (wave attack)". Department of Geography & Environmental Studies, Stellenbosch University.
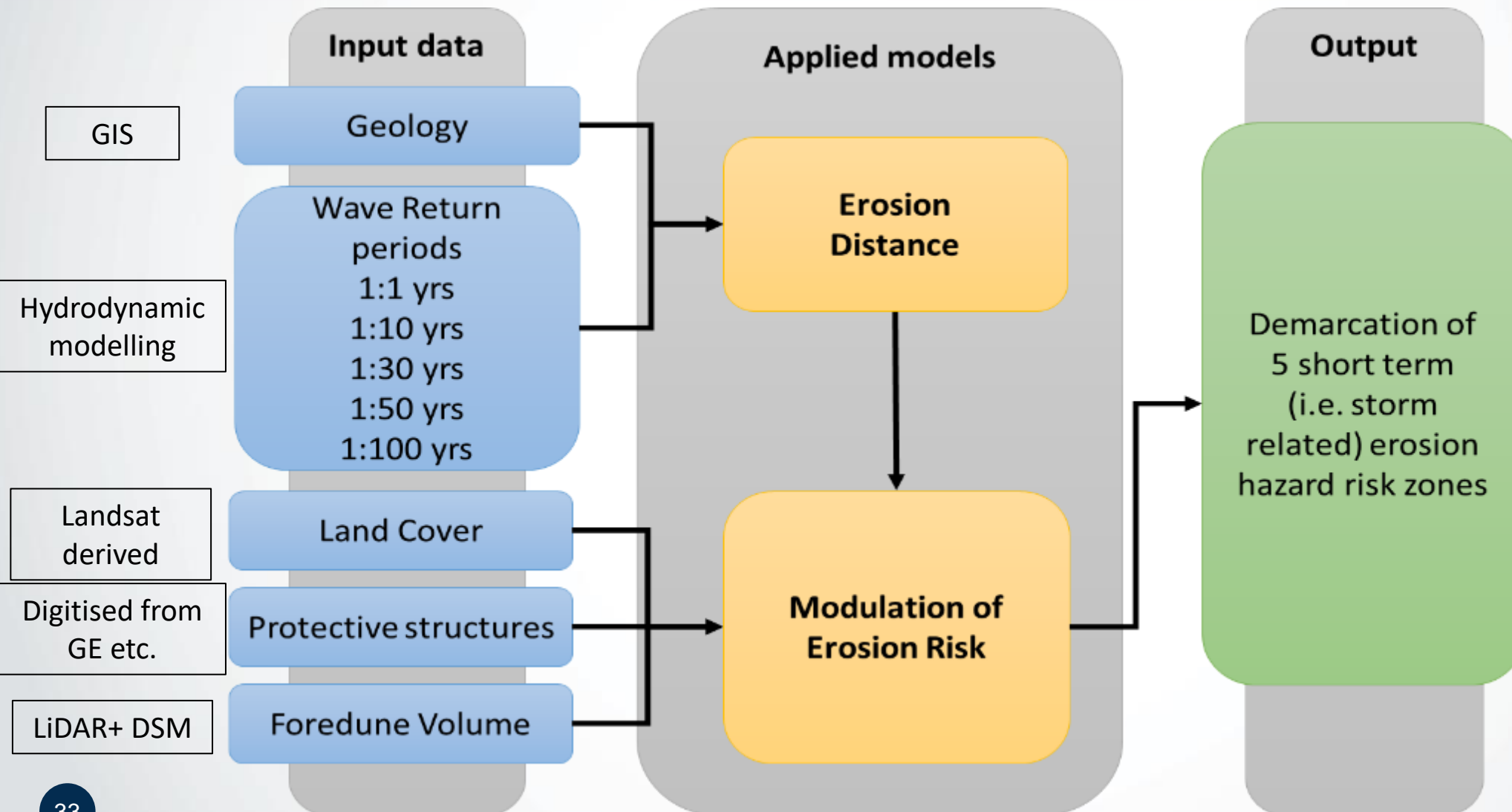
Open Coast Flood Risk Index

Flood risk assessed up to the 20m topo contour

Output cell size: 5 x 5 m

Coastal Climate Change Vulnerability Assessment
- Northern Cape
- Western Cape
  - Coastal Flood Risk
    - very low
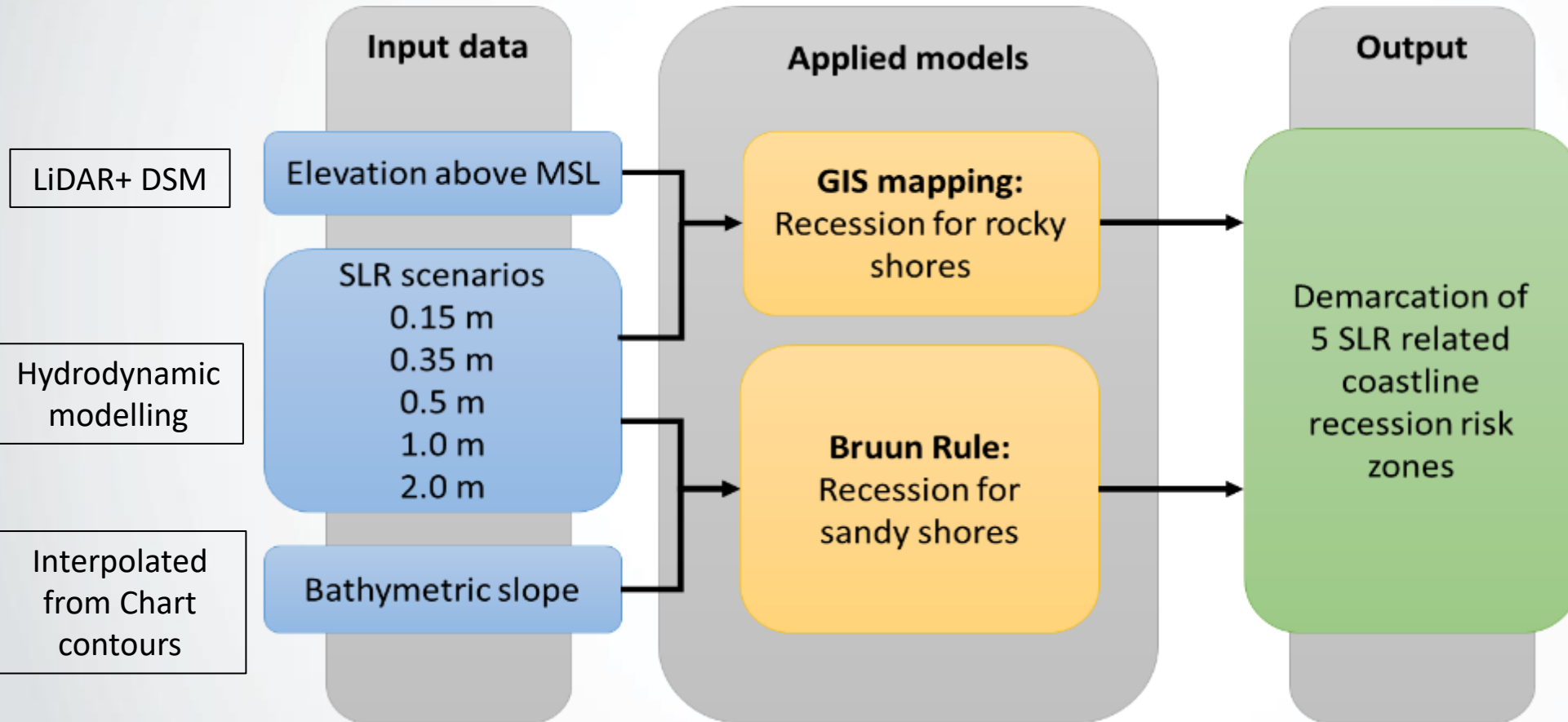   - low
    - moderate
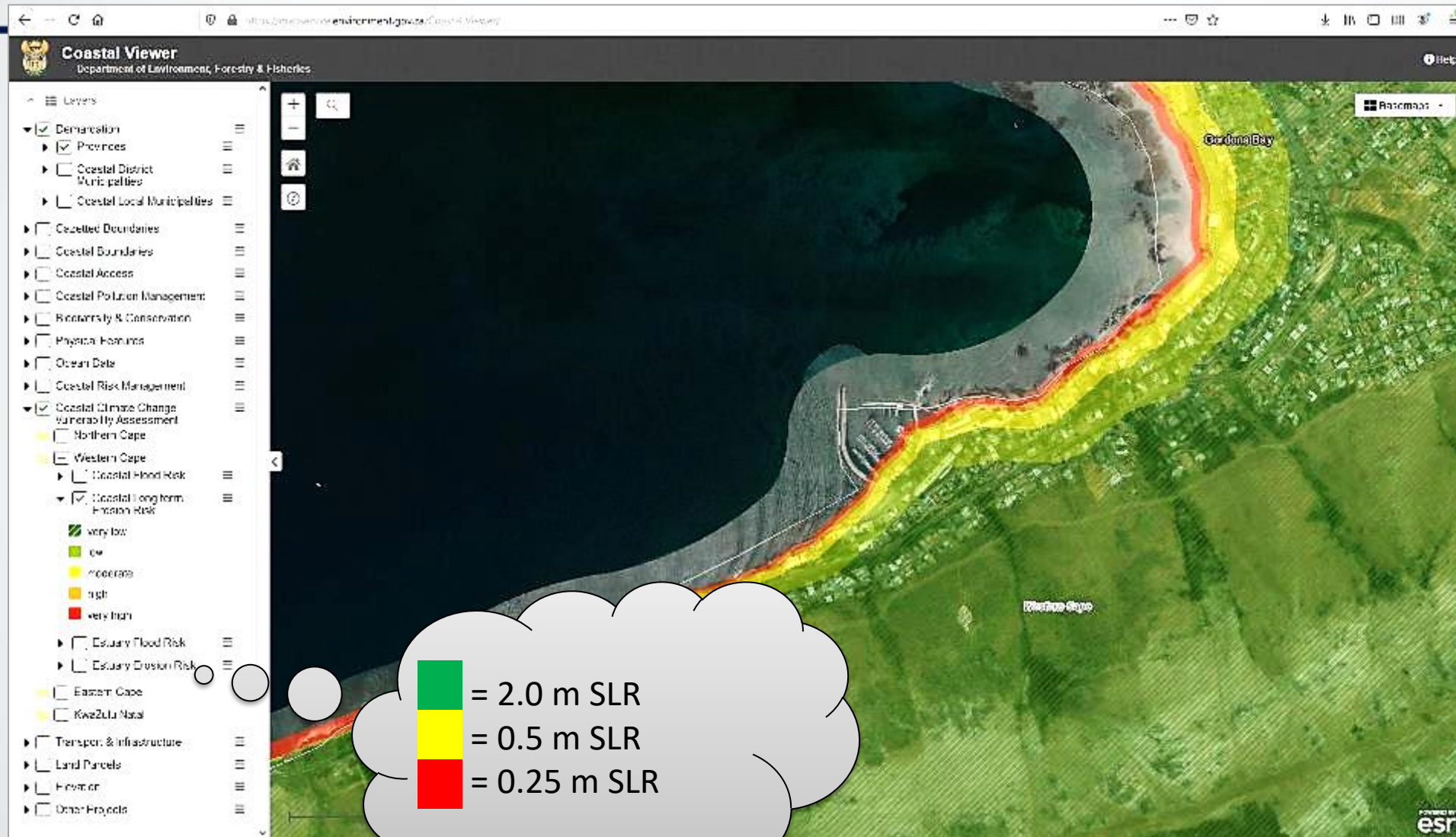   - high
    - very high

Open Coast Short Term Erosion Risk Index

Open Coast Short Term Erosion Risk Index
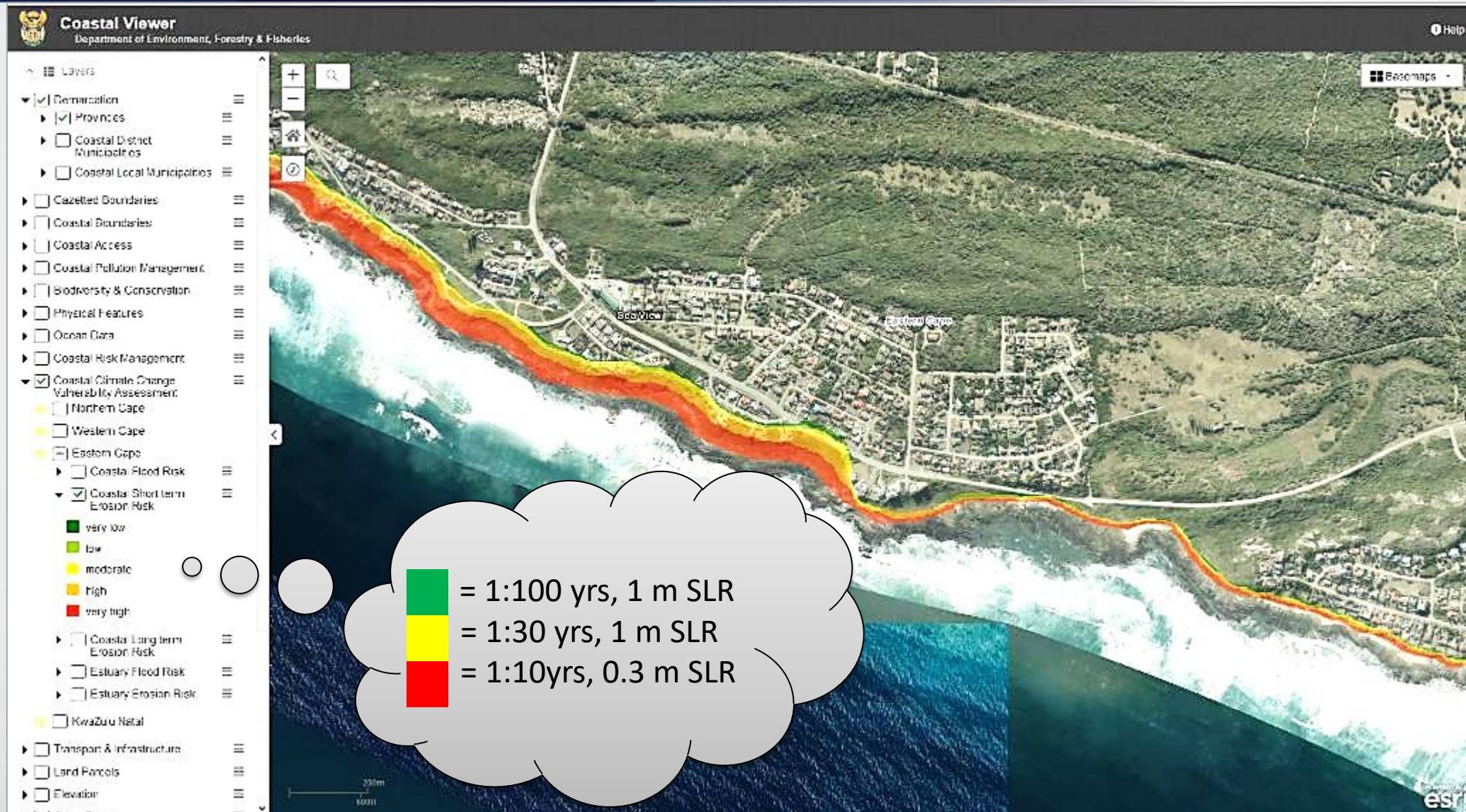
Open Coast Long Term Erosion Risk Index
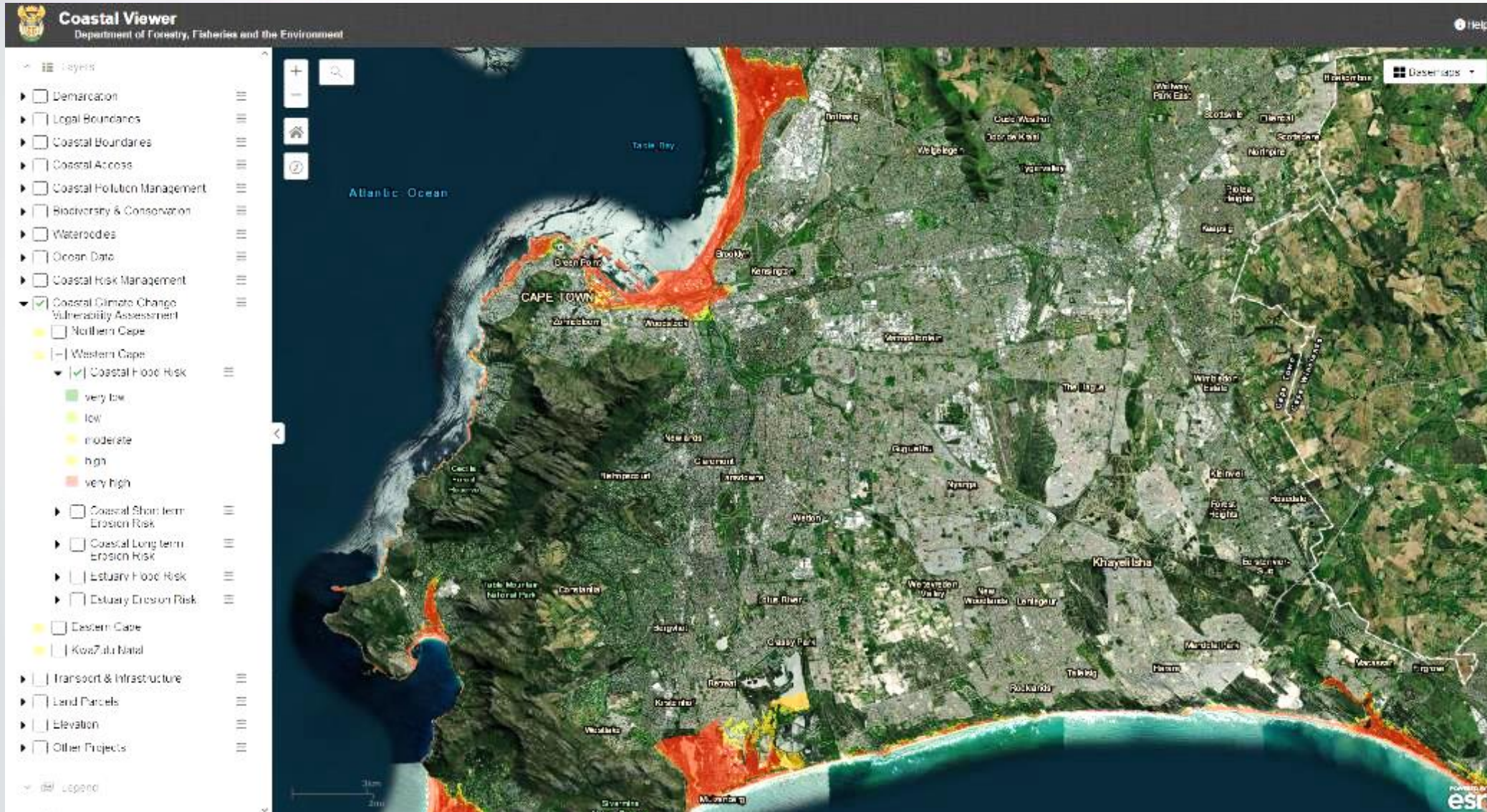
Open Coast Long Term Erosion Risk Index

= 2.0 m SLR
= 0.5 m SLR
= 0.25 m SLR

36

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Estuaries Erosion Risk Index
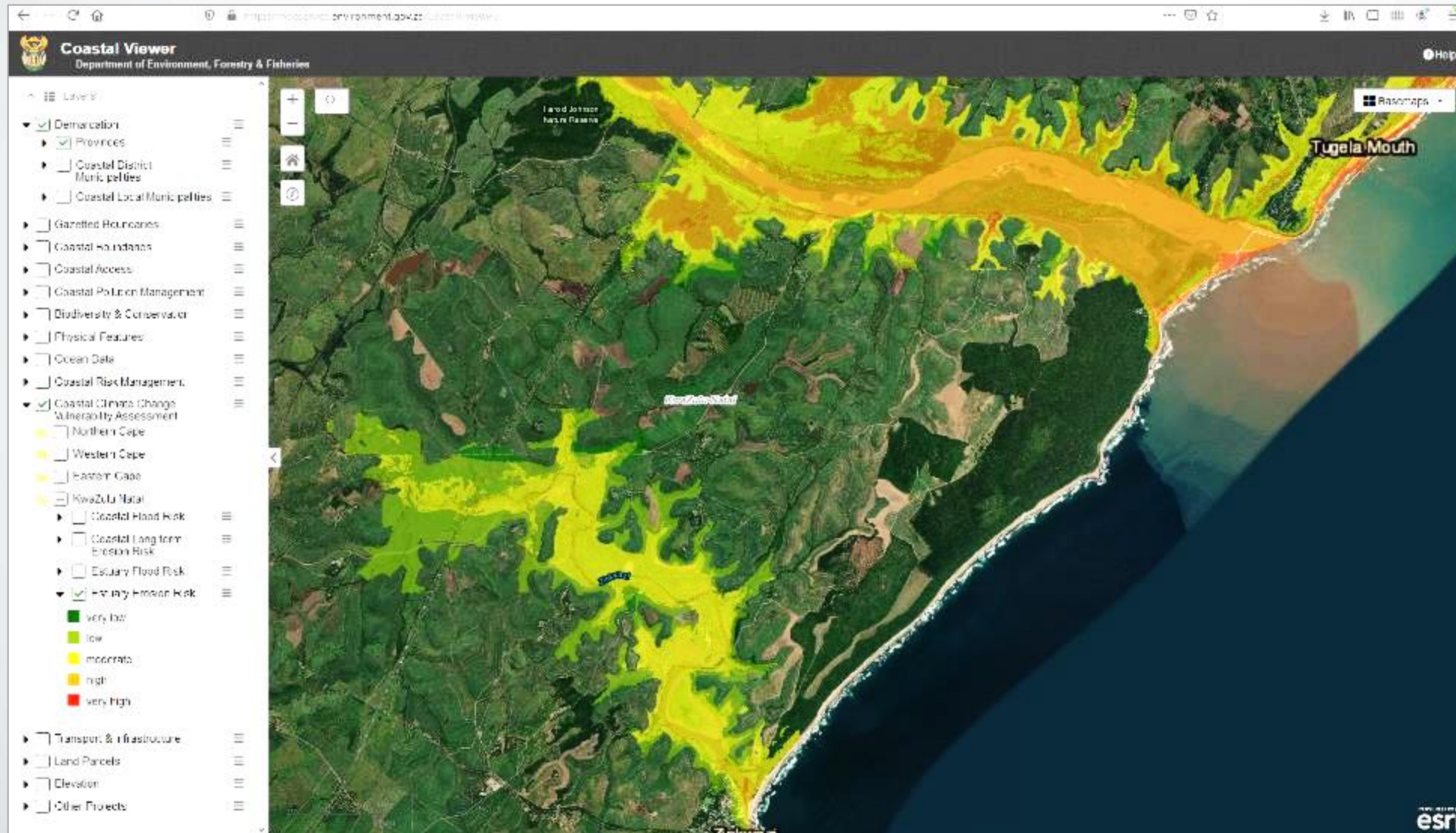
Risk layers available publicly

https://mapservice.environment.gov.za/Coastal%20Viewer/

Strategic Geospatial Data Management

Marine and Coastal Spatial Data Infrastructure development (ongoing)

- Guided by UNGGIM and EU INSPIRE

- Terrestrial SDI long in existence

- Will help to identify key datasets

- Will help to identify custodians with

  mandate/obligation to provide data, e.g.

  high-resolution, up-to-date Elevation
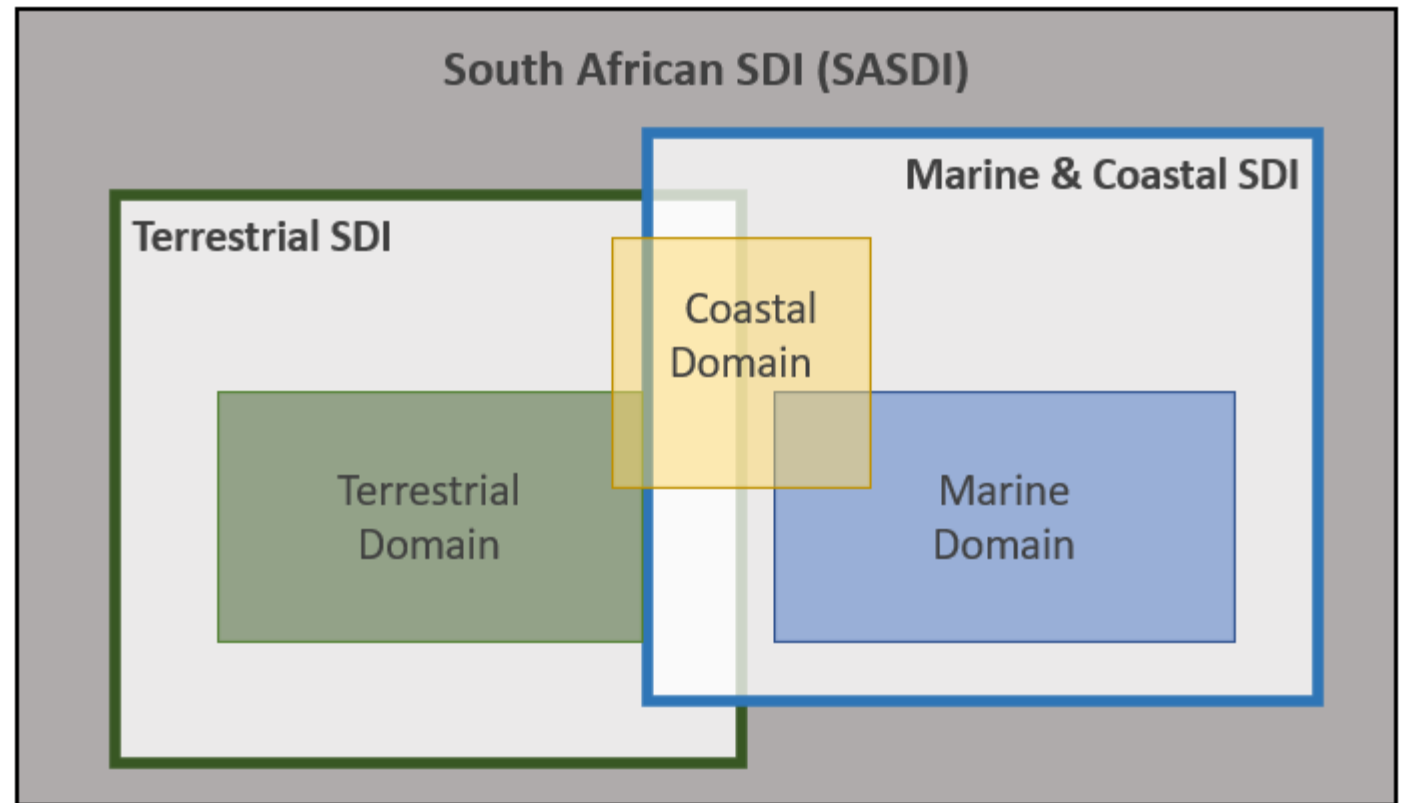
Thank you

Melanie Lück-Vogel

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