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Contribution of Artificial Intelligence to analysis and cartography the dunes



DOCTORAT **ECOLOGIE**
BRETAGNE **GEOSCIENCES**
LOIRE **AGRONOMIE ALIMENTATION**

2021-2024

Why map aeolian dunes ?

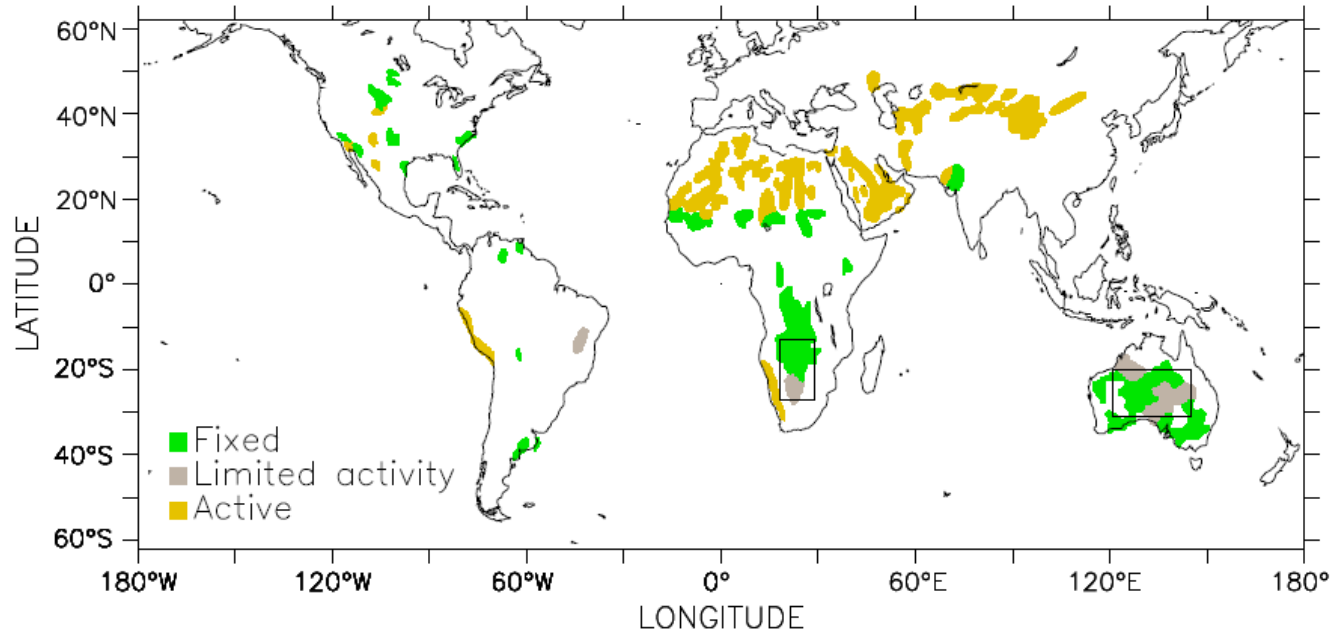
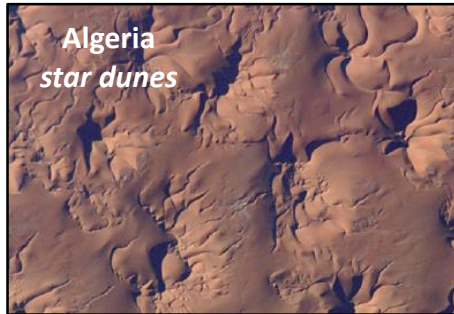
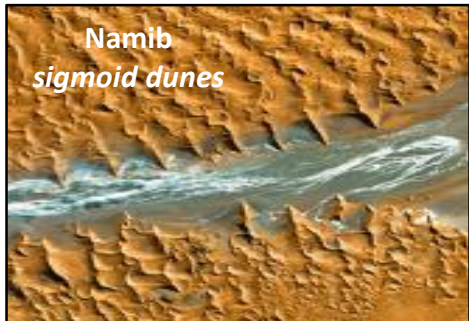
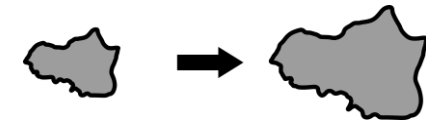


Figure 1: A map of the world's dune areas, divided into active (yellow), limited activity (gray), and fixed (green) regions (Ashkenazy and al., 2012). The rectangles indicate the areas whose properties are summarized in Ashkenazy and al., 2012.

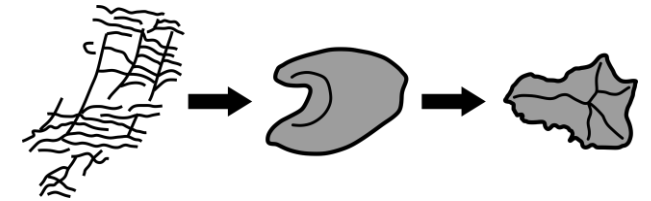


Some different forms/sizes/spacings

Elementary or mature form?

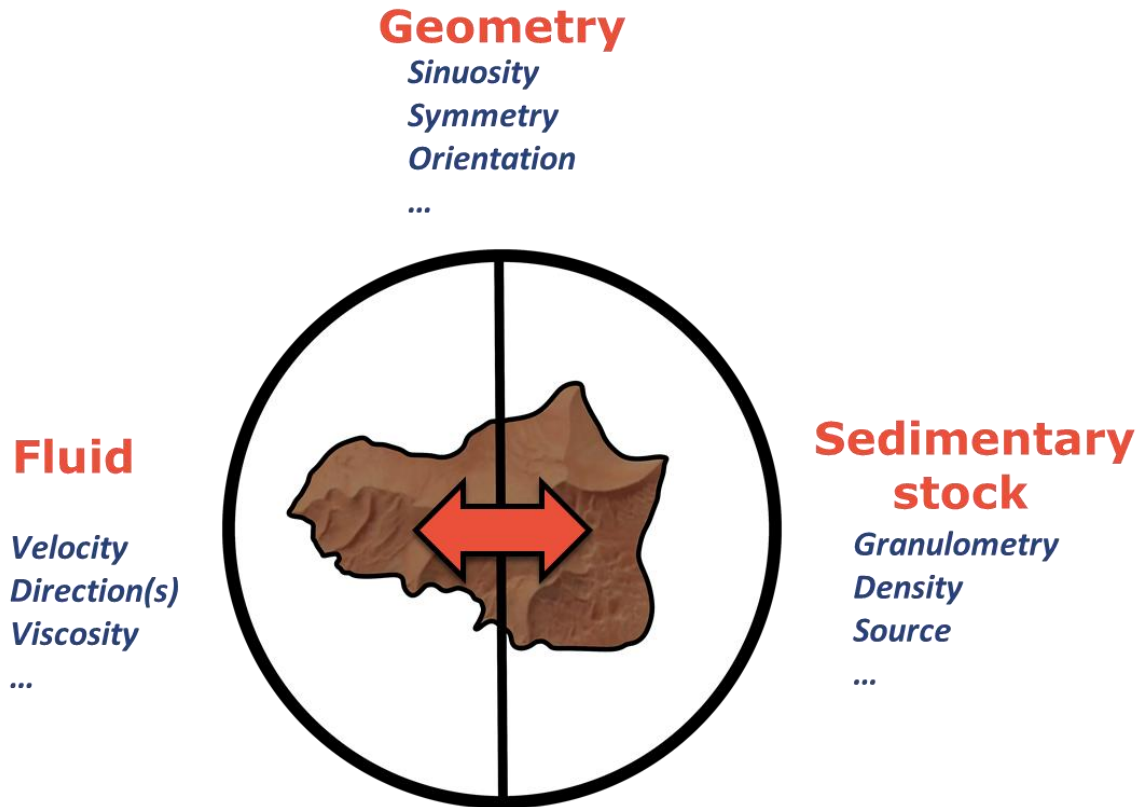


Continuum?

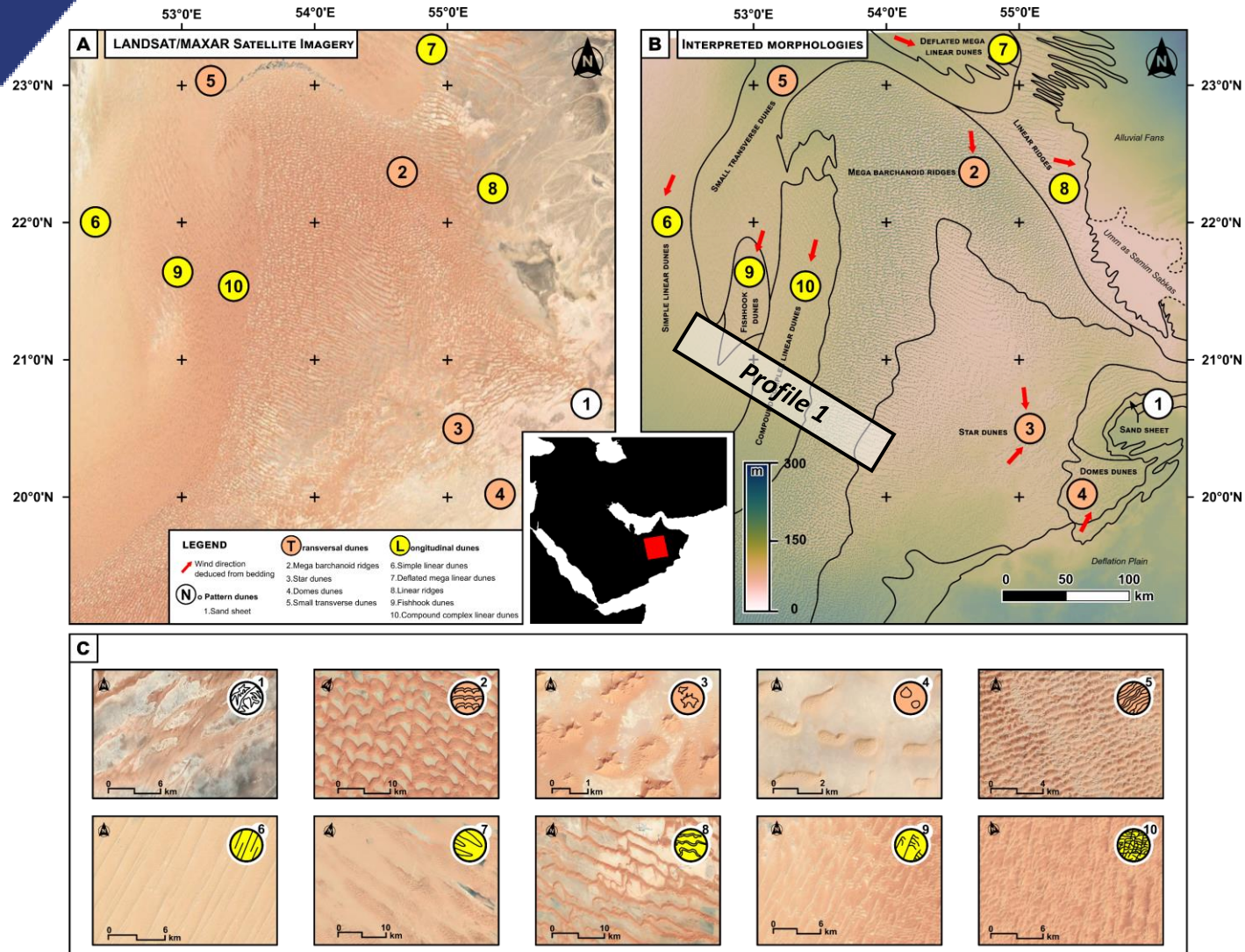


Same processes on Earth as other planets?



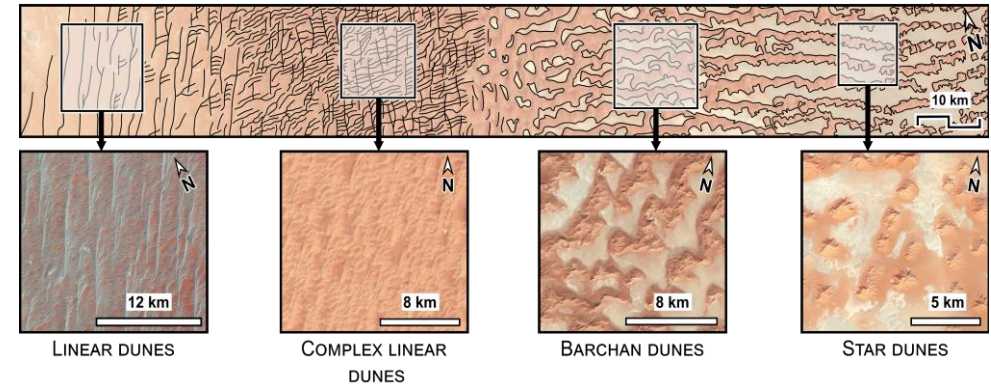


- 1** *Develop a semi-automated protocol*
- 2** *Analyze form/characterize processes*
- 3** *Reconstruct fluid dynamics from independent data*



SPATIAL VARIABILITY

Profile 1



Clustered patterns

Isolated patterns

- Presence of several dune morphologies,
- Marked borders between different morphologies,
- Spatial evolution of pattern,
- Spatially clustered sedimentary patterns (figure 5).

Figure 4: Synthetic map of sedimentary morphologies generated from bibliographic summaries of Barth, 2001; Kumar and Abdullah, 2011; Goudie and al., 2000; Glennie and Singhvi, 2002.

SCALE OBSERVATION

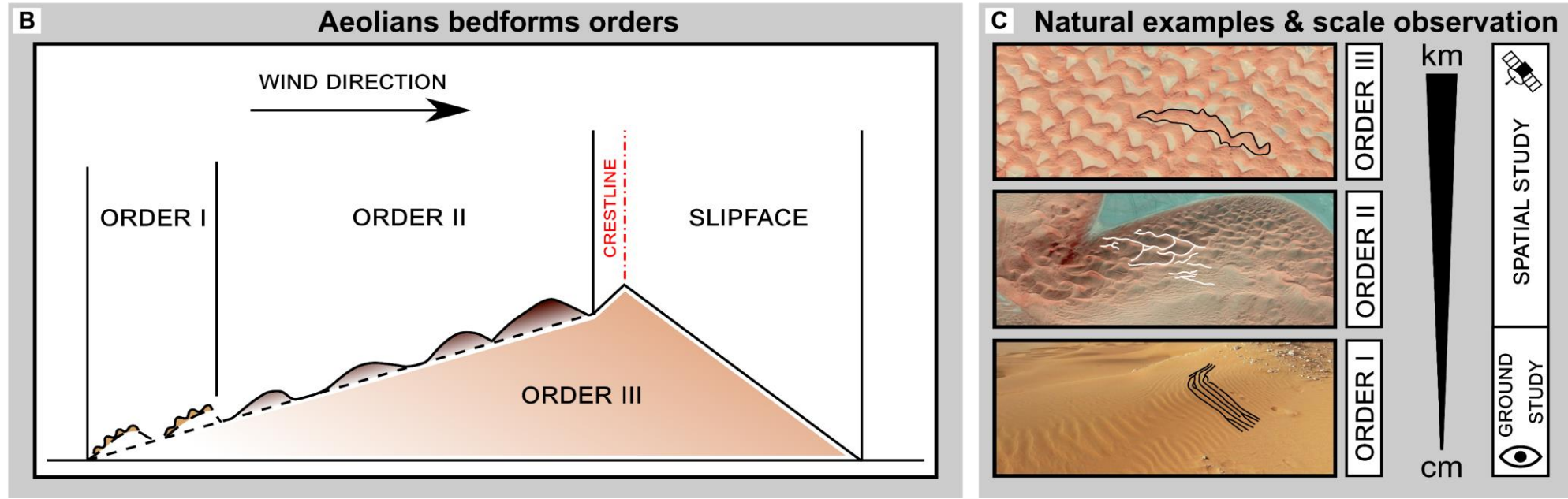
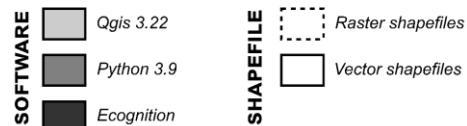
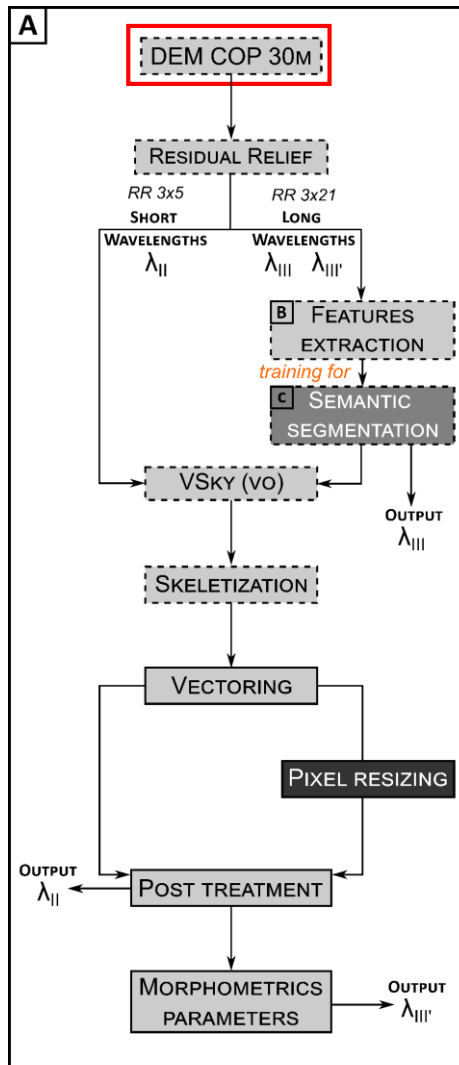


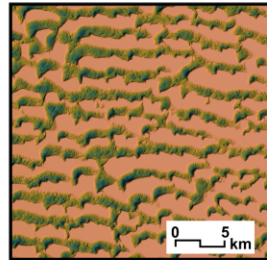
Figure 5: Presentation of different observation scales (b and c) of the Rub'Al Khali dunes.

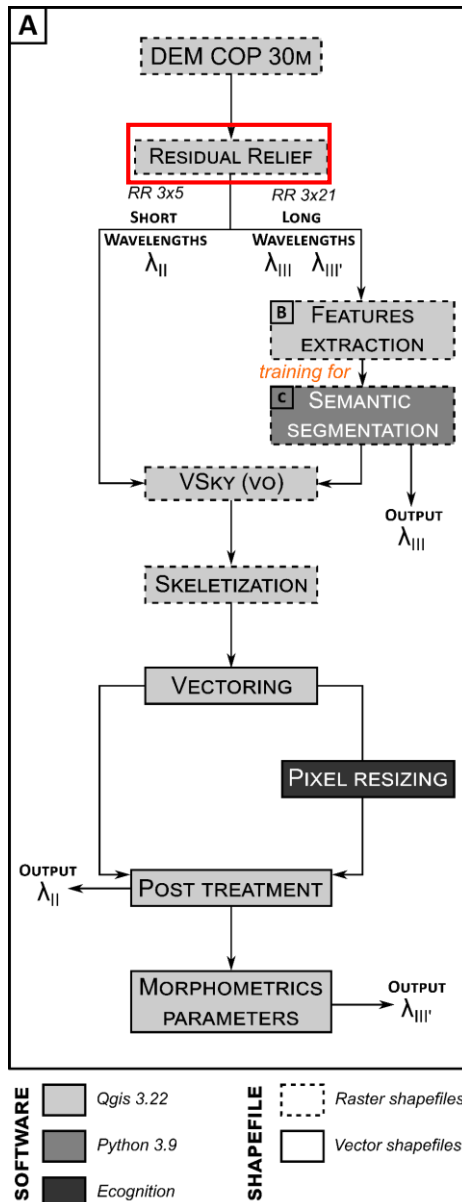
- Presence of different orders of magnitude,
- Order III and II can be acquired by satellite acquisition,
- Order I requires an outcrop study.



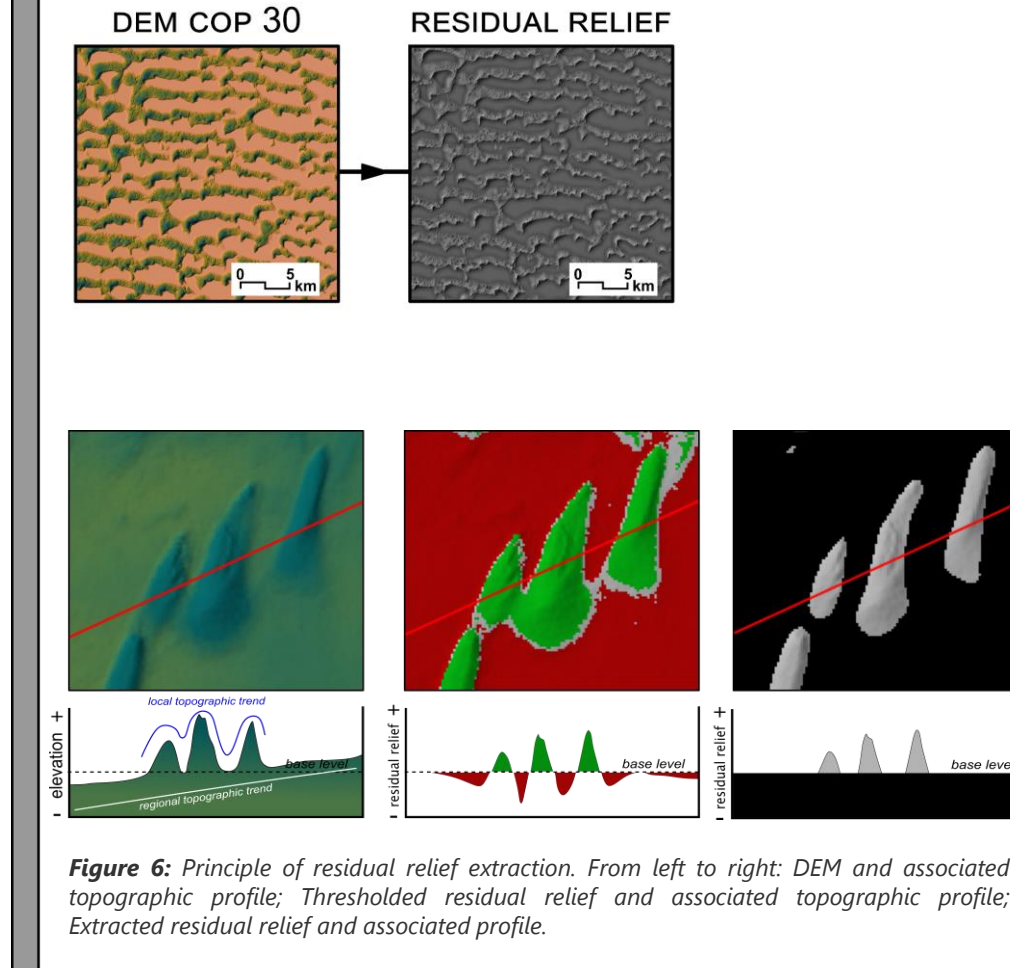
VISUAL OUTPUT SOFTWARE

DEM COP 30



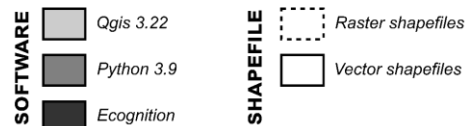
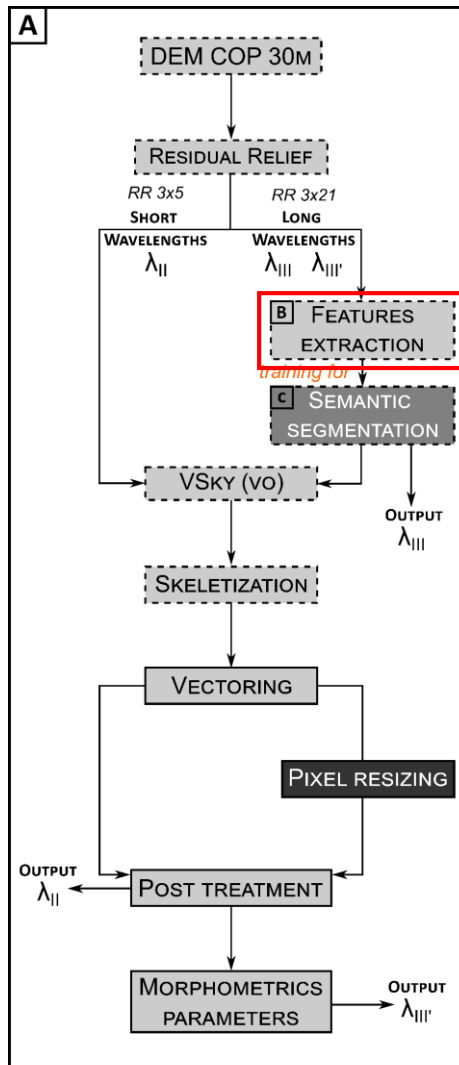


VISUAL OUTPUT SOFTWARE

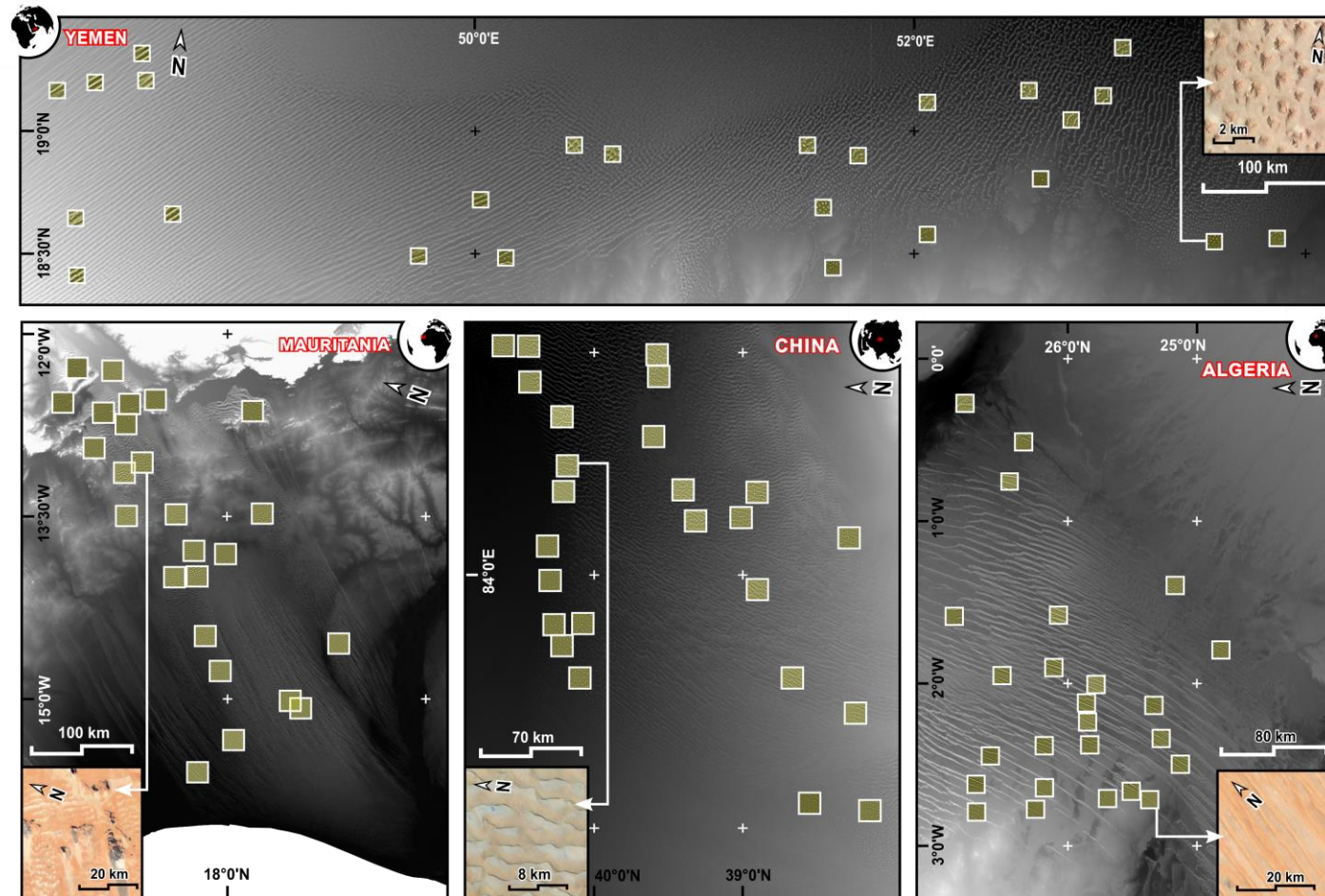


The objective of the residual relief is to suppress the regional topographic trend on a DEM and to preserve the local trends associated at the bedforms.

Key feature for the development of the extraction protocol by Artificial Intelligence.



B FEATURES EXTRACTION



100 residual relief samples created
Resolution: 192x192 pxl

↓
Yemen
[1; 25]

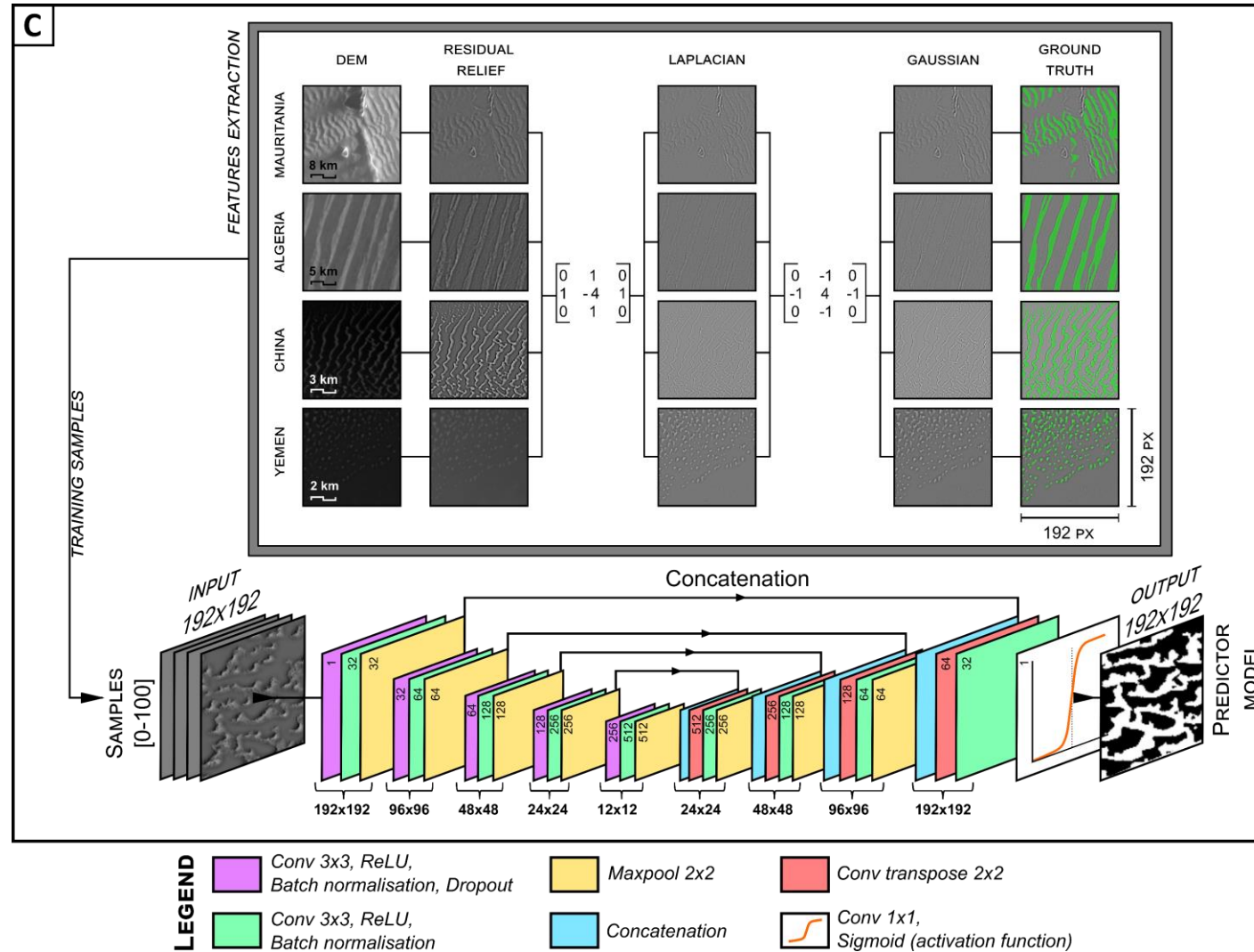
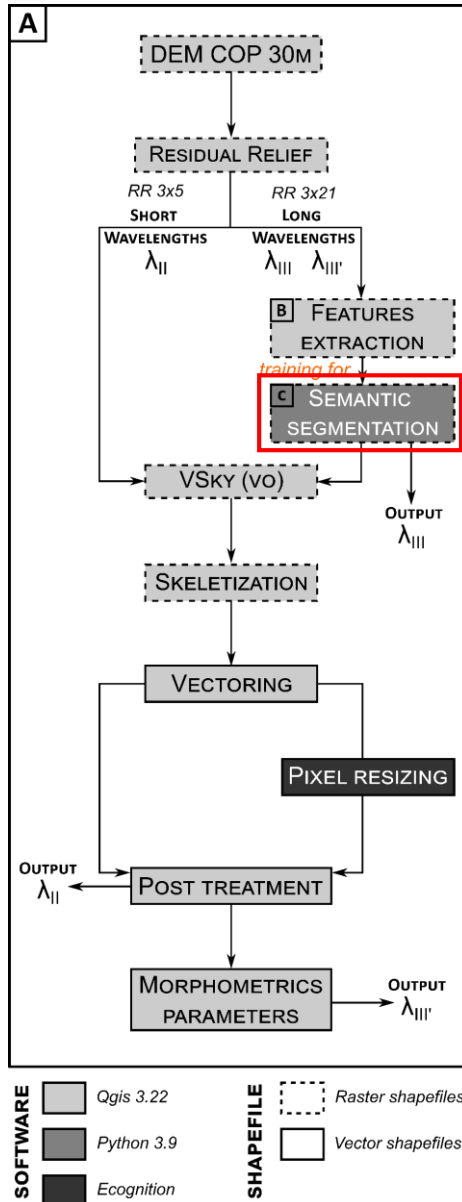
Mauritania
[26; 50]

China
[51; 75]

Algeria
[76; 100]

Figure 7: 100 training sample location map for convolutional neural network (CNN with U-Net architecture) distributed over four sandbank (Yemen, Mauritania, China, Algeria). Each yellow box represent one sample of 192x192 pxl.

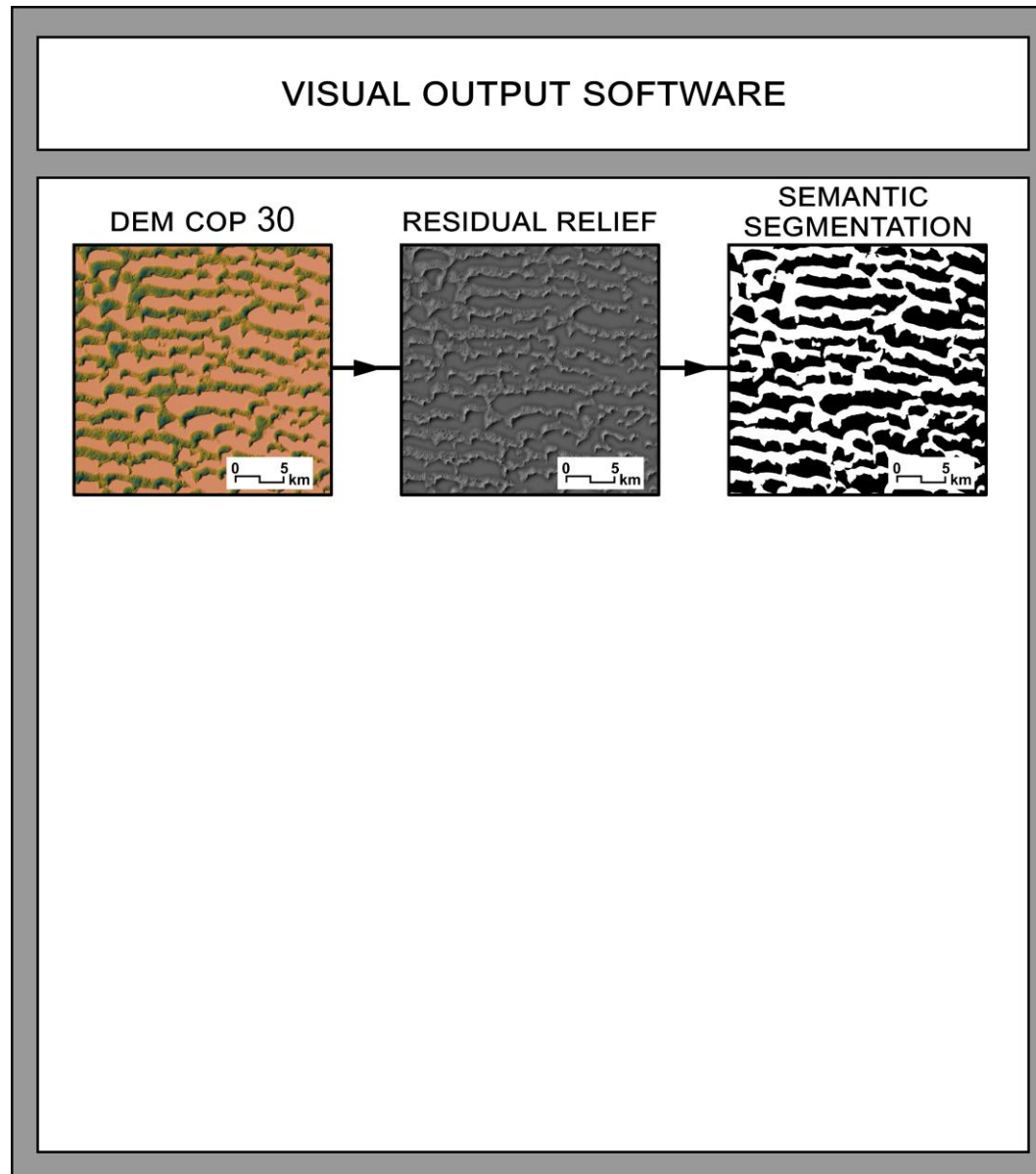
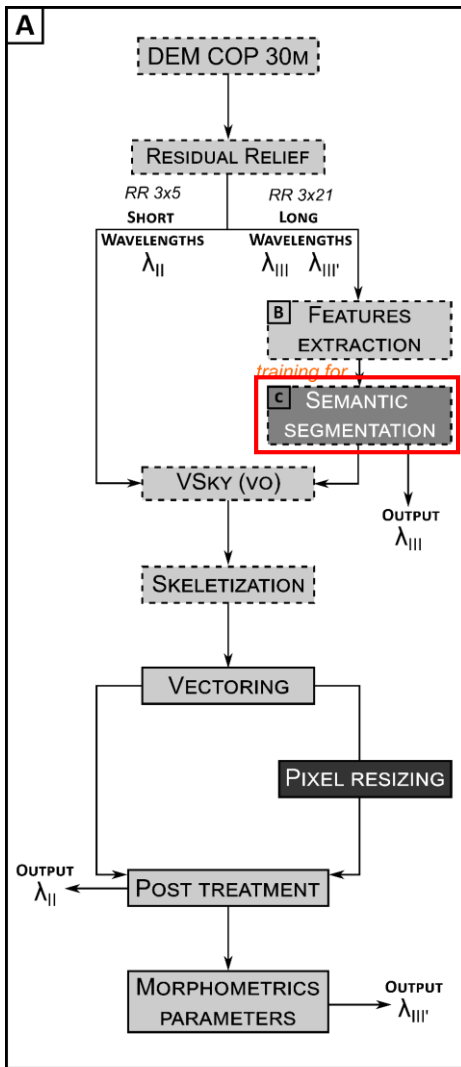


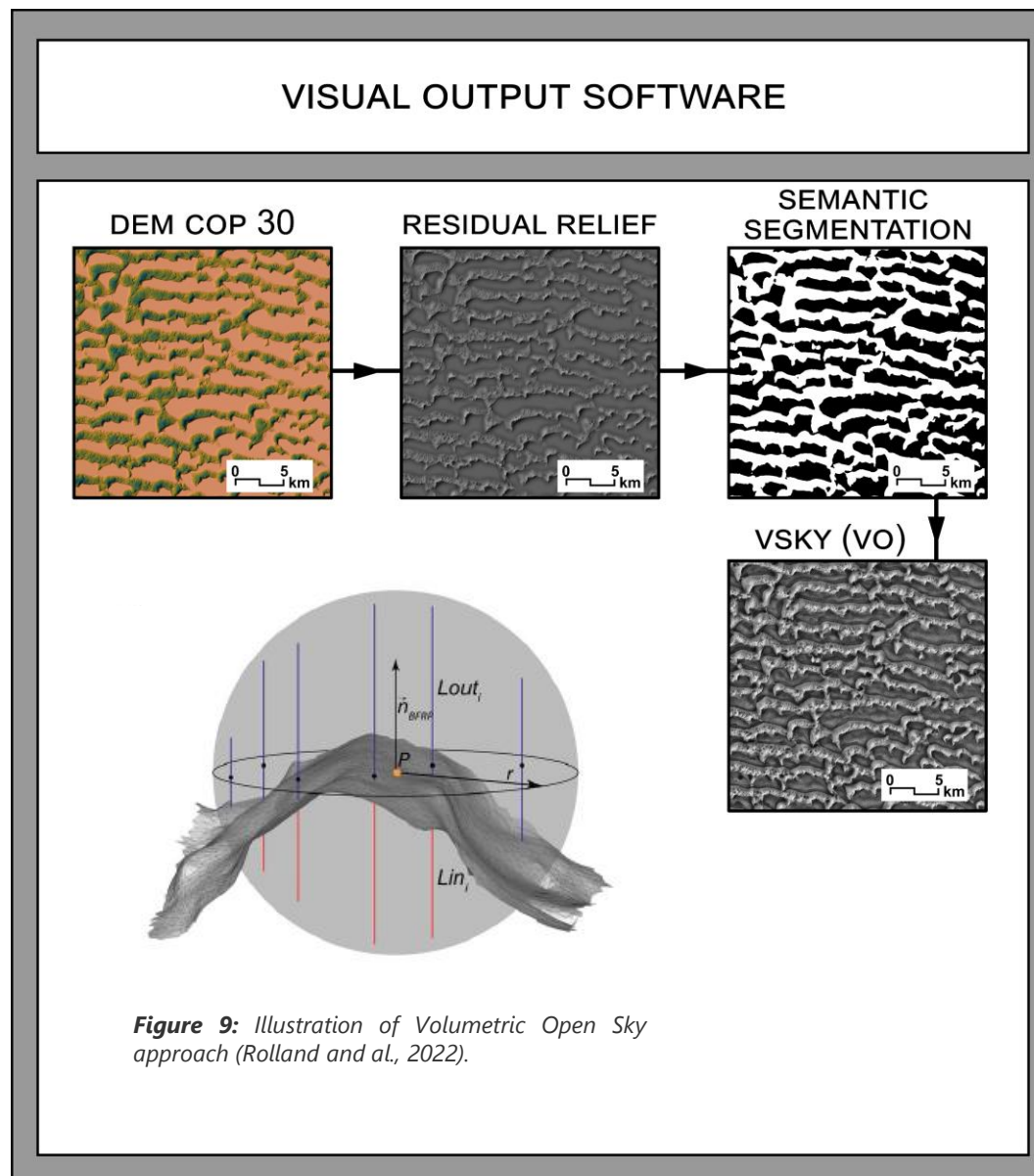
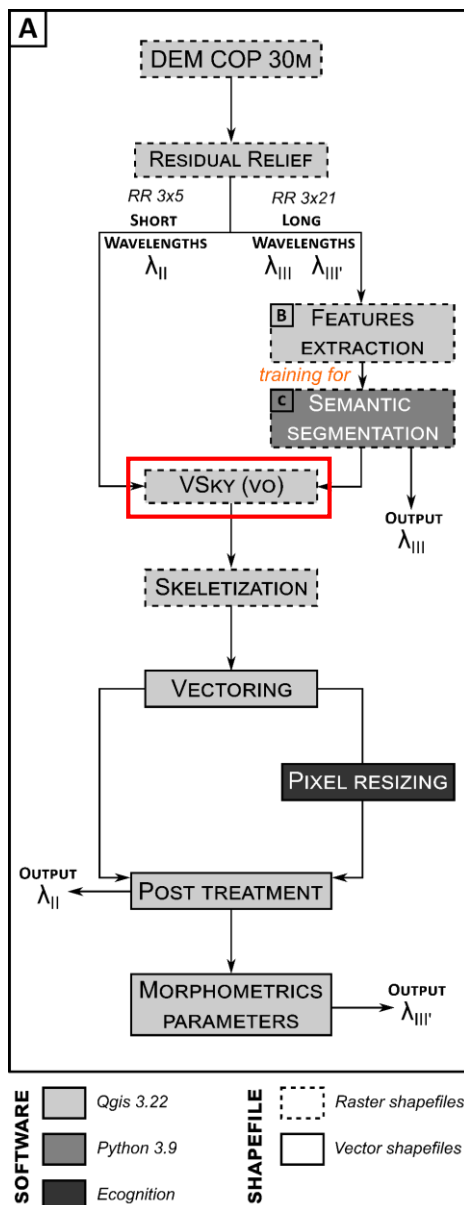


IoU= 71%
Accuracy= 93%

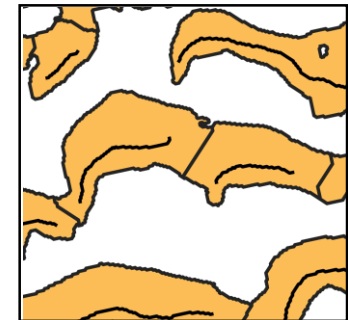
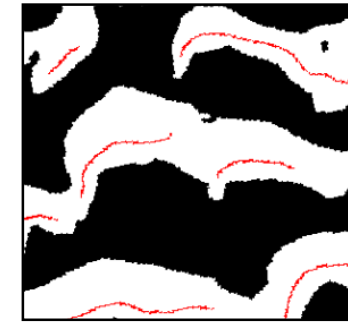
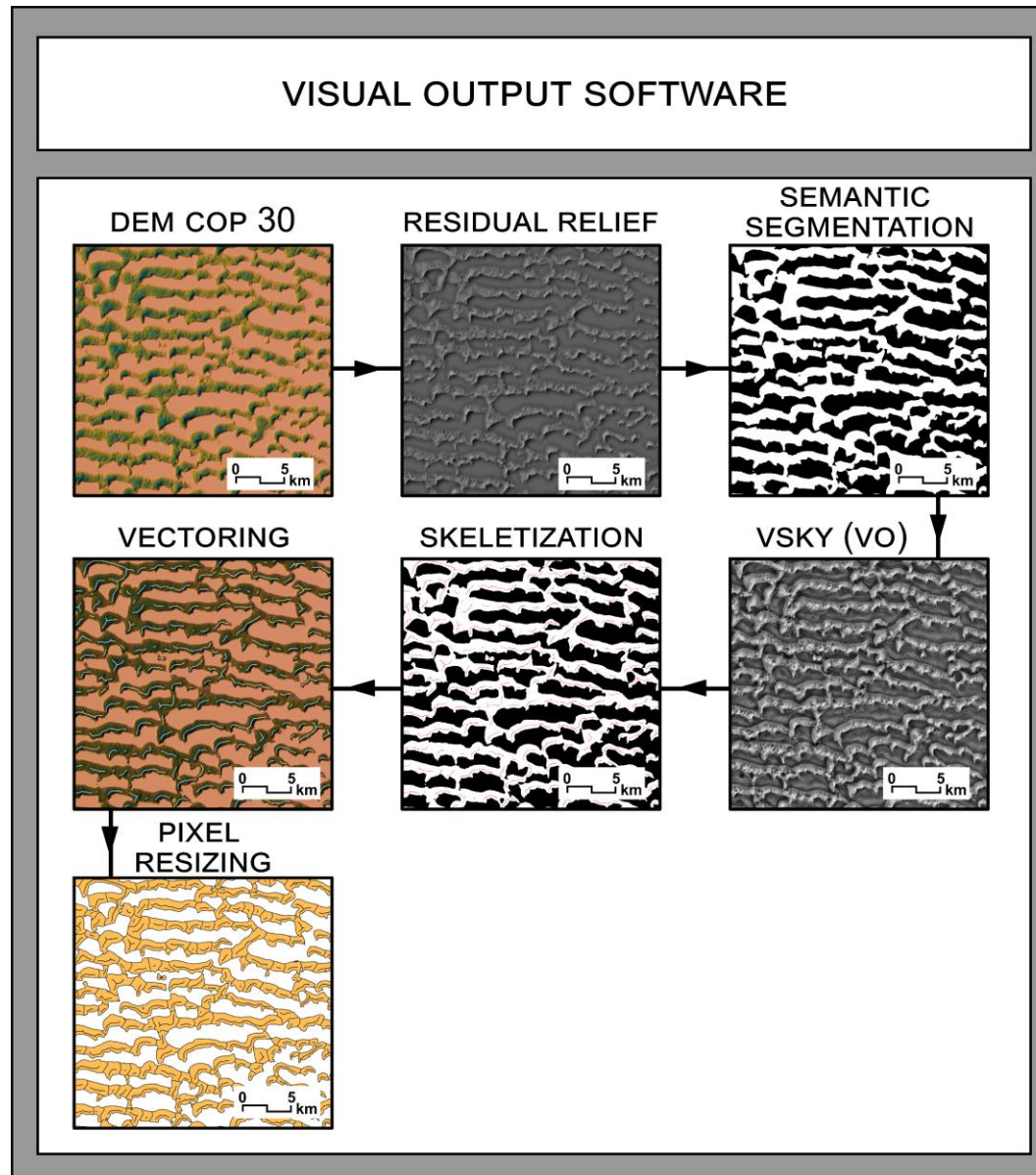
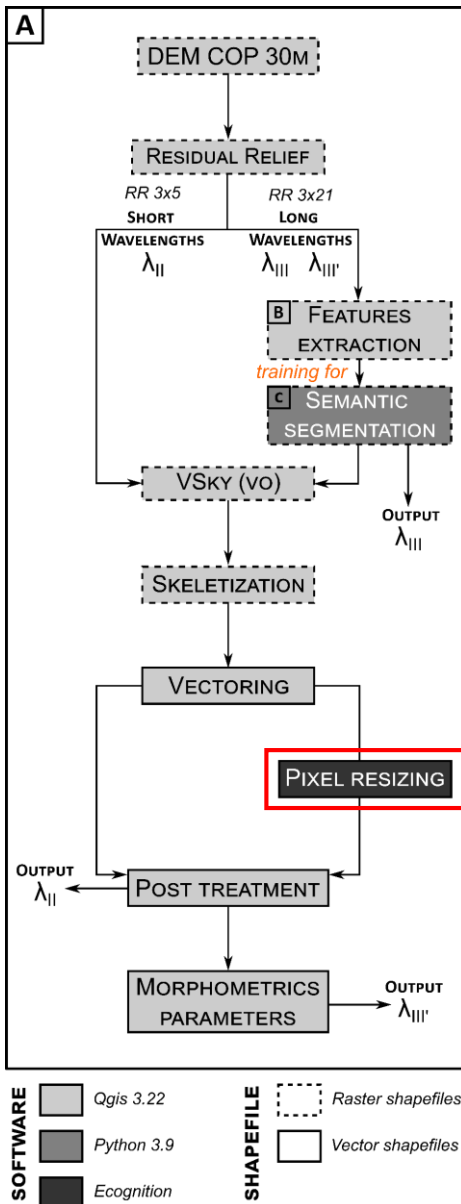
Figure 8: Data-flow diagram showing the method of bedforms pixel classification followed by extraction of bedforms vectors from CNN (U-Net) method (modified from Shumack and al., 2020).



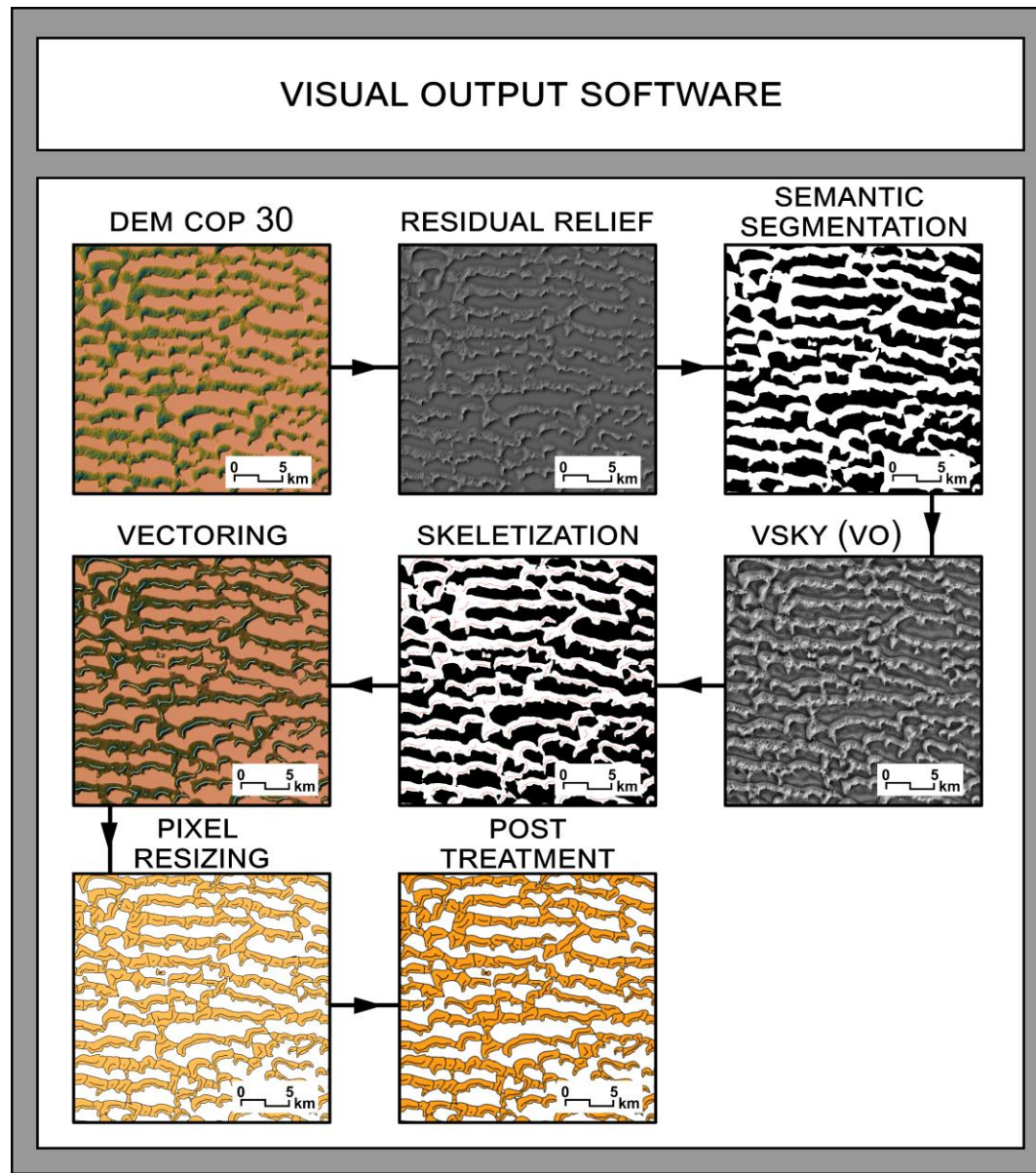
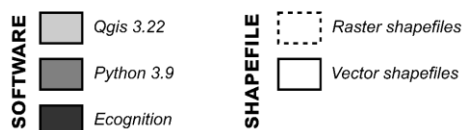
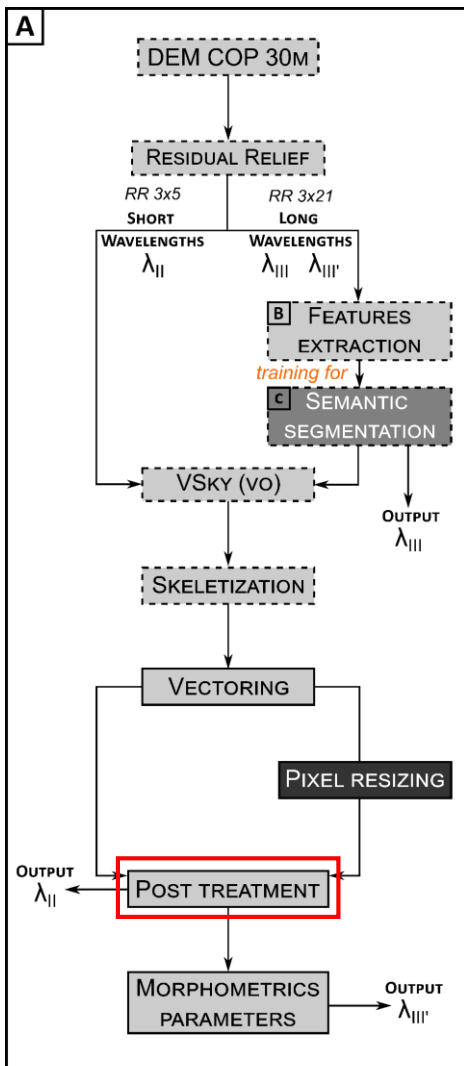


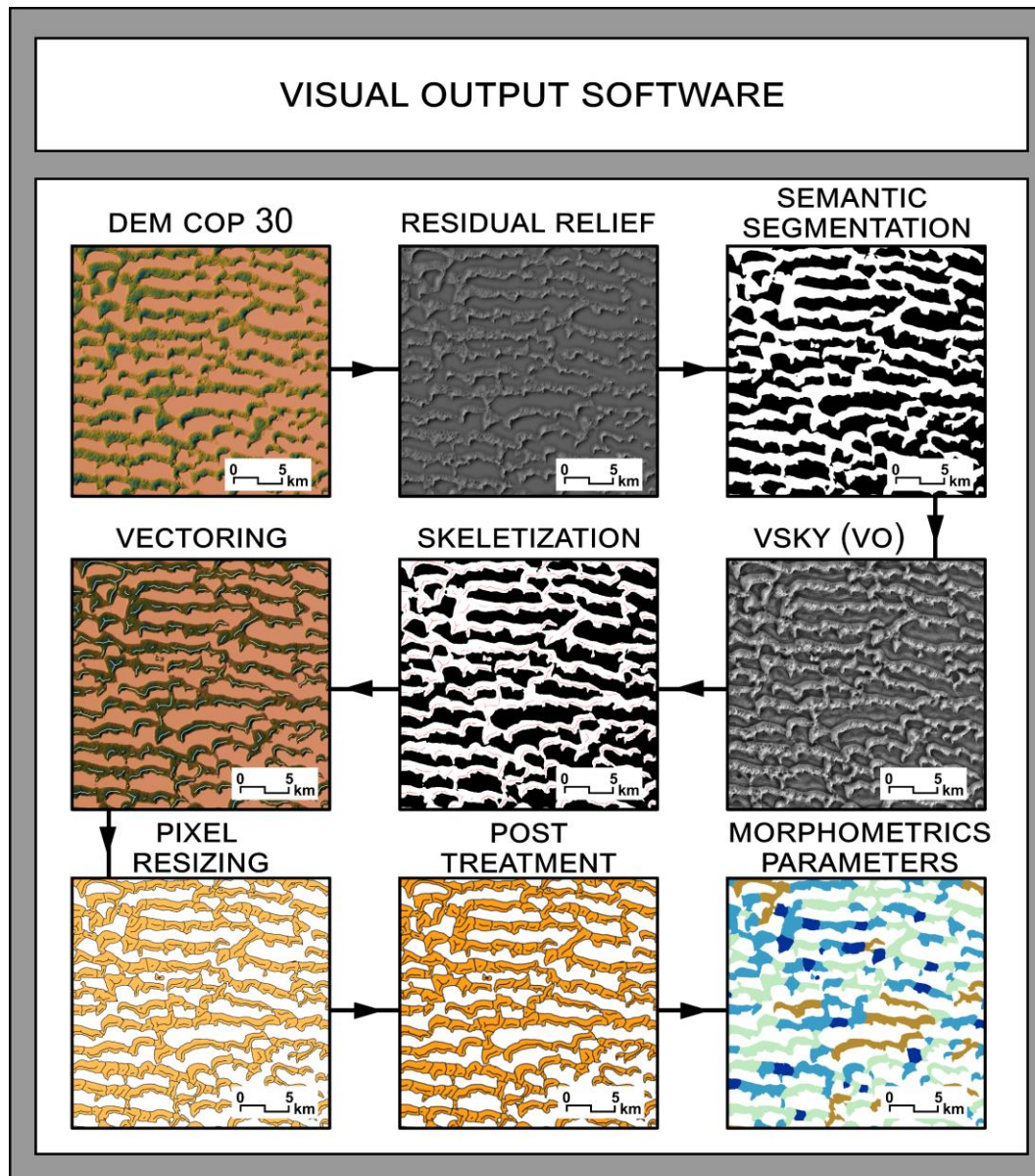
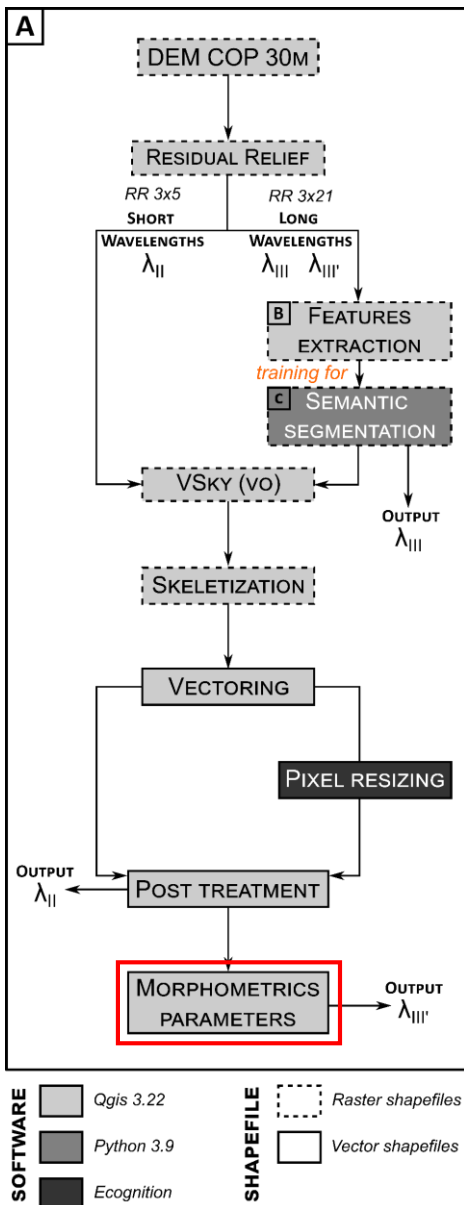


Amplification of the positive and negative values of the relief at a point (P) contained in a sphere of chosen radius (r).



Growth of ridge lines until they come into contact with neighboring lines (individualization of forms)

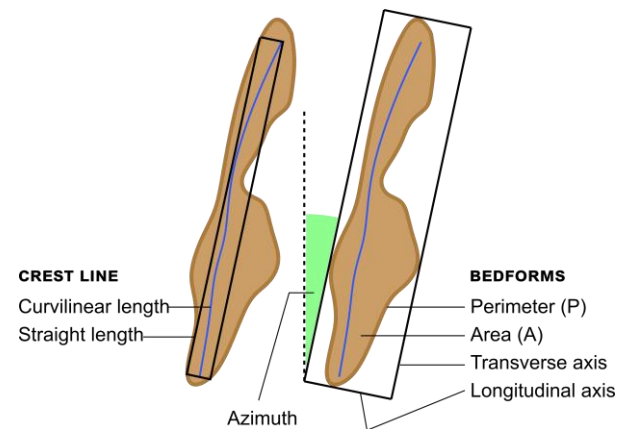




Being processed ...

Morphometrics parameters

Vérité and al., 2022



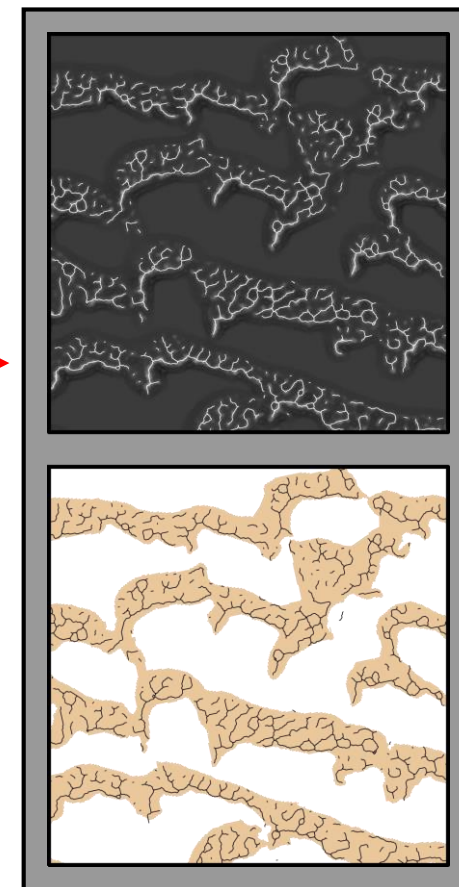
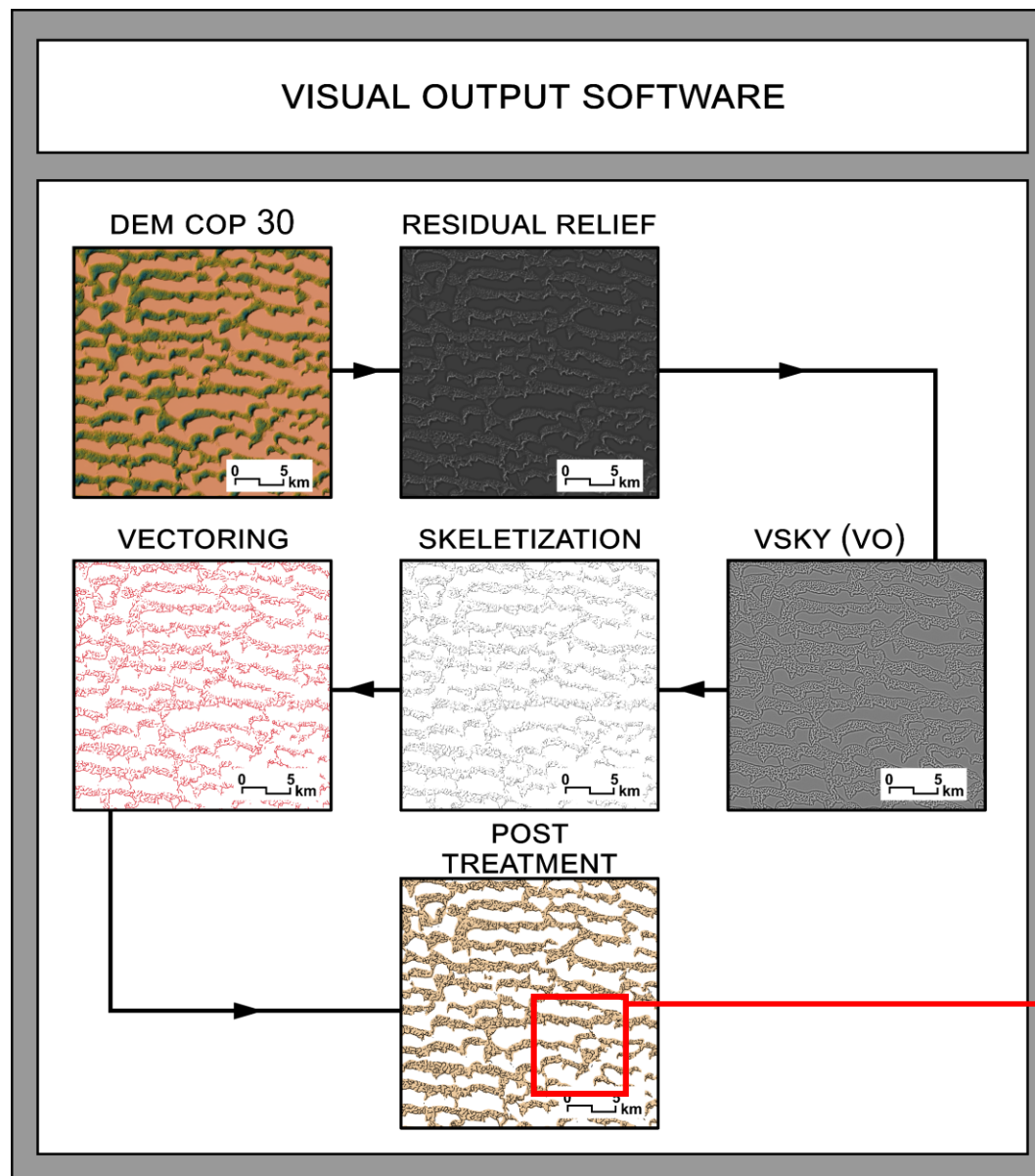
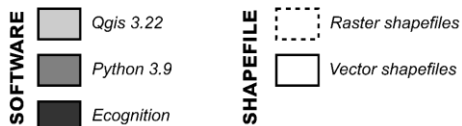
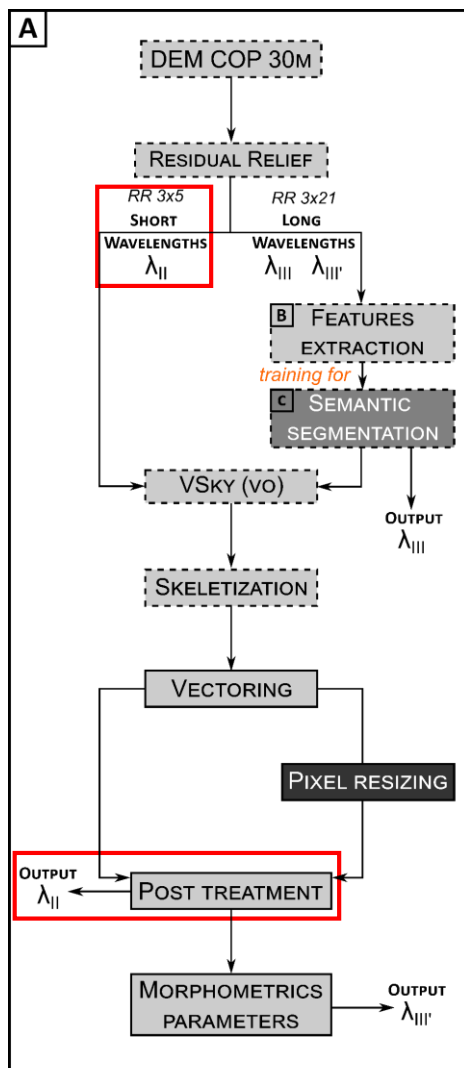
Elongation (El)

= Transverse axis / Longitudinal axis

Circularity index (I_{circ}) = $(4\pi A) / P^2$

Sinuosity index (I_{sin})

= $((\text{Curvilinear length} / \text{Straight length}) - 1) / (\sqrt{5} - 1)$



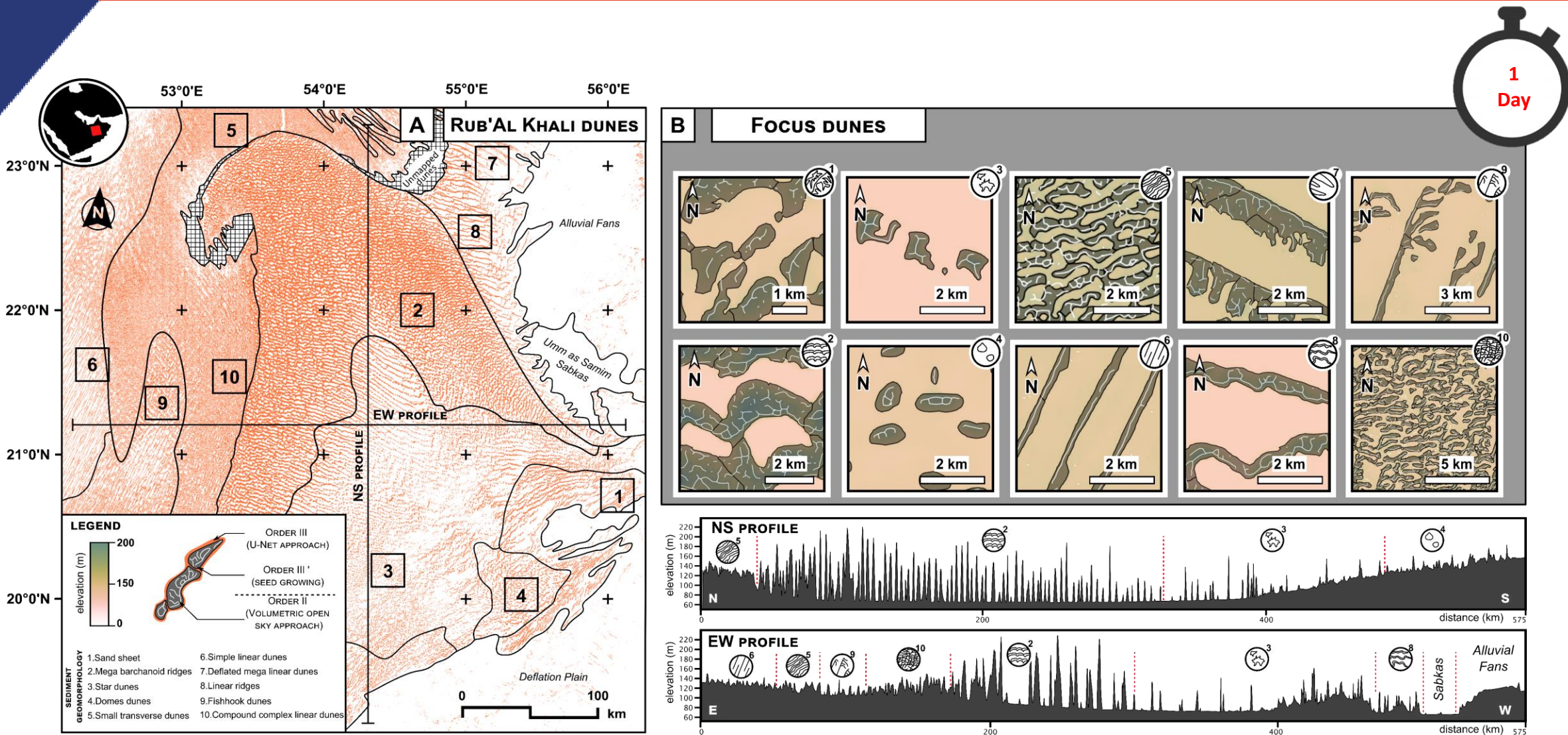
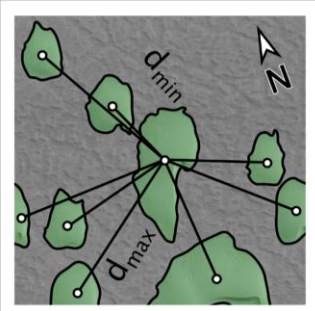


Figure 10: Map of the different of aeolian dunes of the Rub'Al Khali basin (2 observation scales) digitized by semi-automatic approaches (Deep Learning (U-Net), seed growing, Volumetric open sky). A) Map of order III dunes. B) Focus on order III' and order II dunes. each numbered rectangle corresponds to the focus of a type of dune.

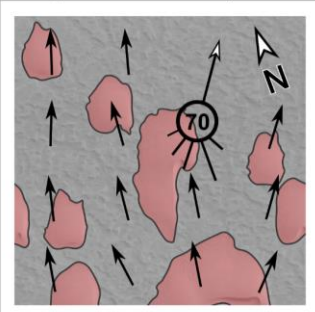
MORPHOMETRIC & DYNAMIC ANALYSIS

NEIGHBORHOOD (distance, distribution etc.)



Use of neighborhood relationships to quantify dune dispersion.

SEDIMENTARY DYNAMICS (wind speed, sand potential drift etc.)



Use of drift potential relationships, flux calculation, wind speed (Fryberger, 1979; Tsoar, 2005; Livingstone, 2007, Ashkenazy and al., 2012) to identify the sedimentary dynamics of dunes.

APPLICATION TO A NEW ENVIRONMENT

