# COASTAL MONITORING FROM SPACE

## ESA'S SEA STATE MEETING 2021

24 March 2021

Erwin W.J. Bergsma

Earth Observation Lab of the French Space Agency

A cooperation between CNES, LEGOS, SHOM, USAC

Sea states: CNES; LEGOS, Ifremer, Météo France.



# Overview

1. **Coastal continuum - bathymetry / topography from space (locally)**

2. **Bathymetry at regional scales**

3. **Sea states using optical satellite imagery**
   *Wave energy spectra*

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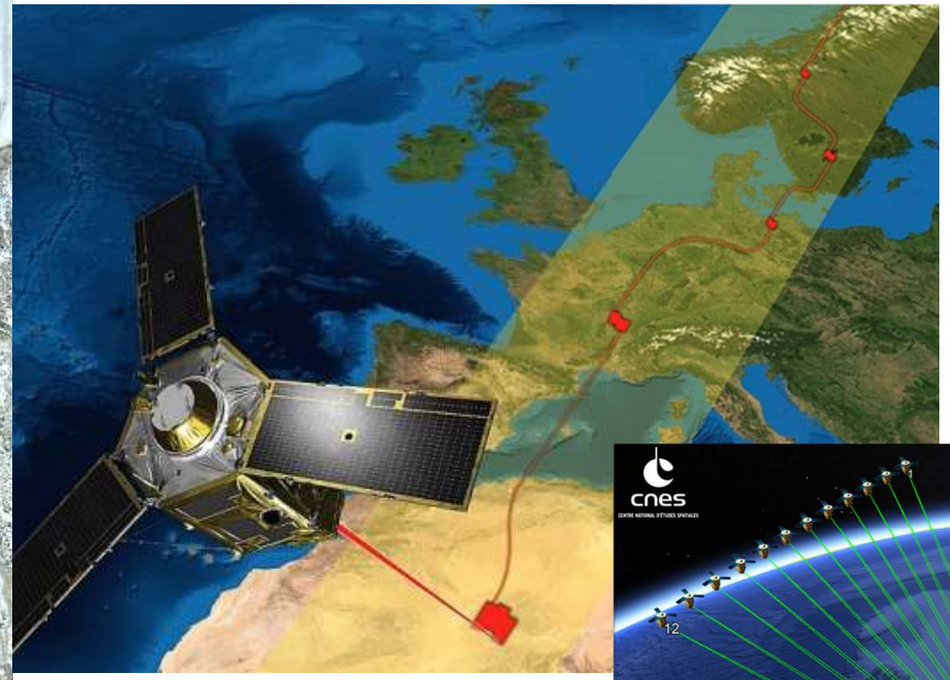
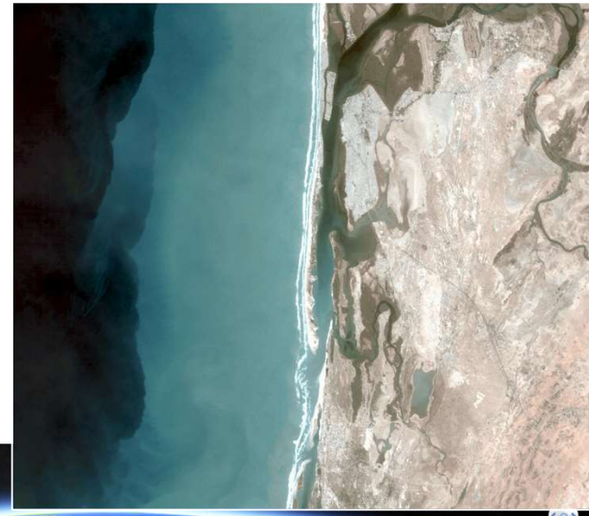
# COASTAL CONTINUUM

## LARGE SCALE COASTAL ZONE MEASUREMENTS

# Current capability

*What can we do with an agile very high resolution satellite?*

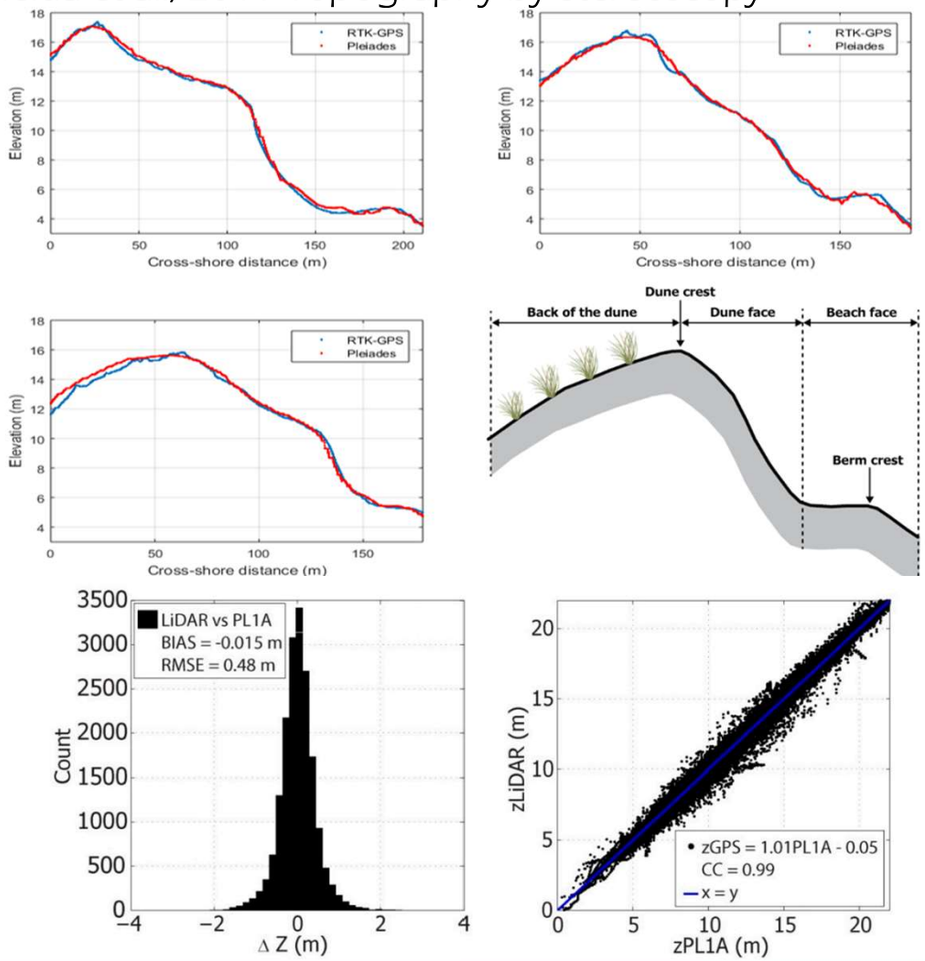




# Current capability; Pleiades

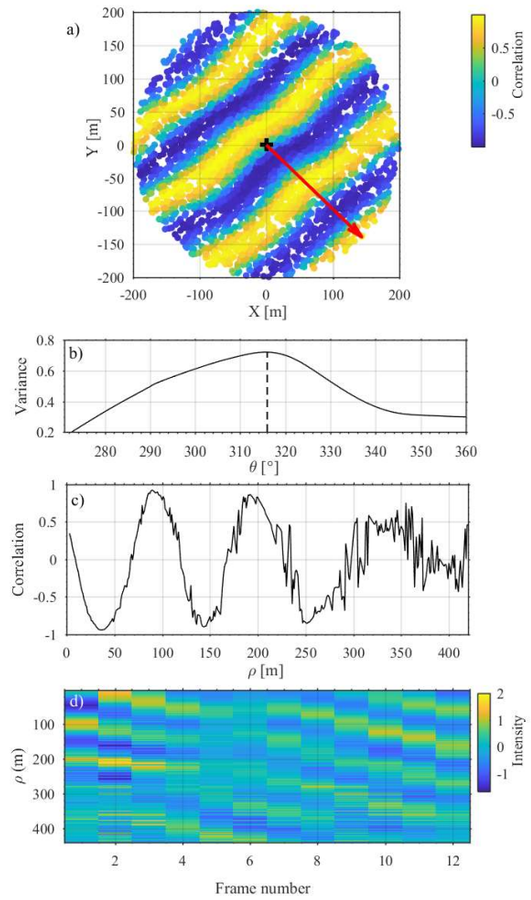
*Pleiades Topography (with insitu known points (GCPs):*

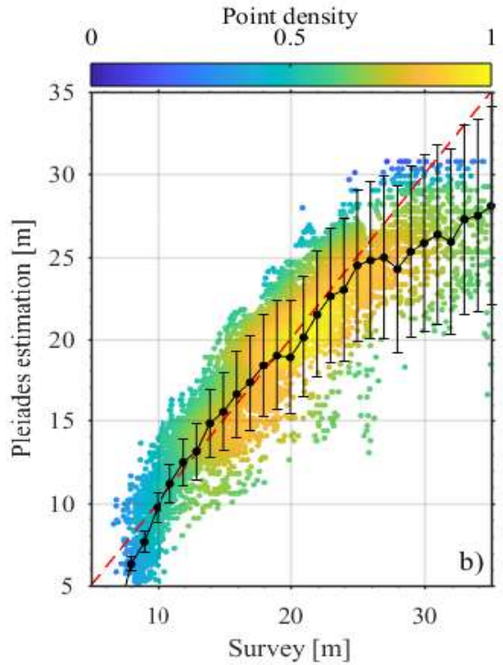
*Almeida et al., 2019 Topography by Stereoscopy*




*Pleiades bathymetry.*

*Almar et al., 2019, bathymetery by wave tracking*



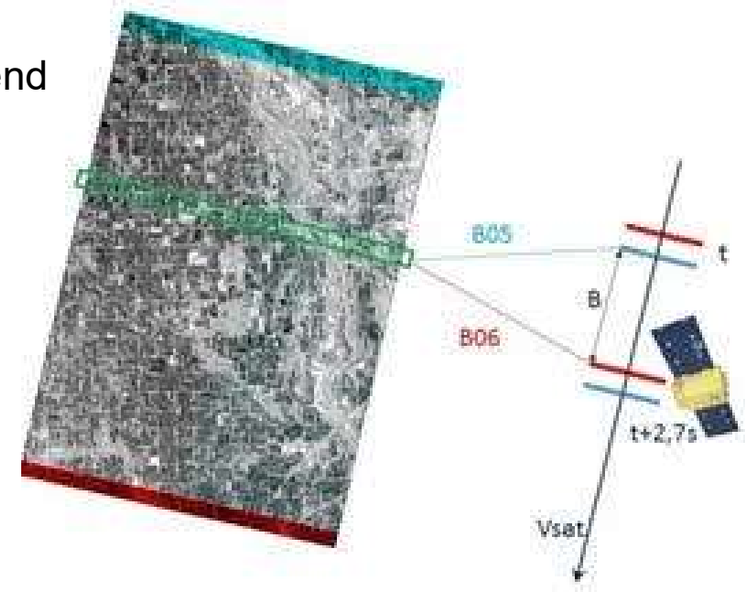



# Can we bring this to a more Sentinel 2 like satellite?

Joint CNES, Israeli Space Agency mission **VENµS:**
Vegetation and Environment monitoring on a New Micro-Satellite

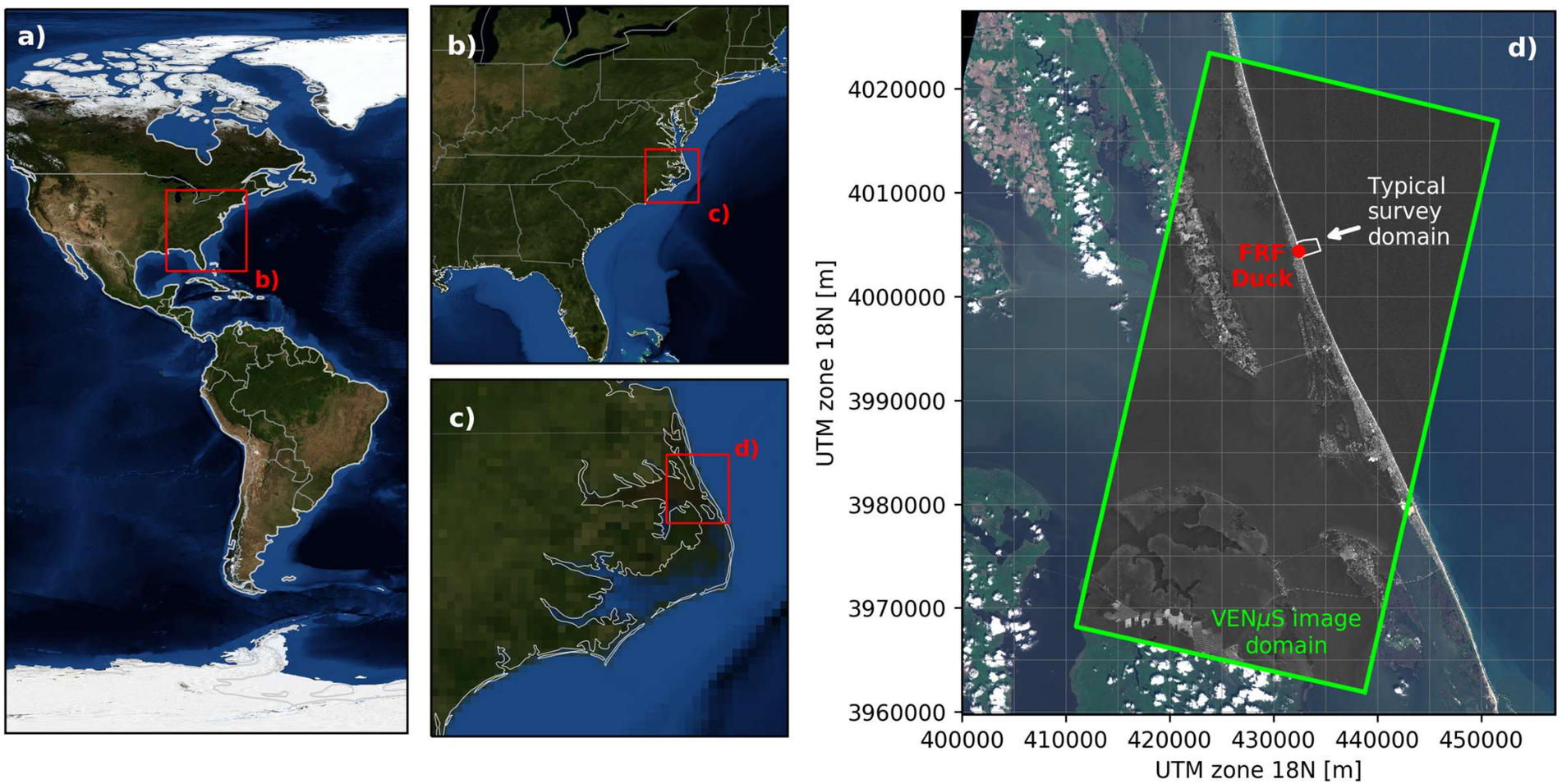
A test-platform for future missions like Sentinel 2:
Revist **: 2 days** (1st phase mission)
Ground sampling resolution : **5 m**
Repetitive identical bands at the start and end of the acquisition that enables:

- DEM approximation
- Depth inversion using identical bands



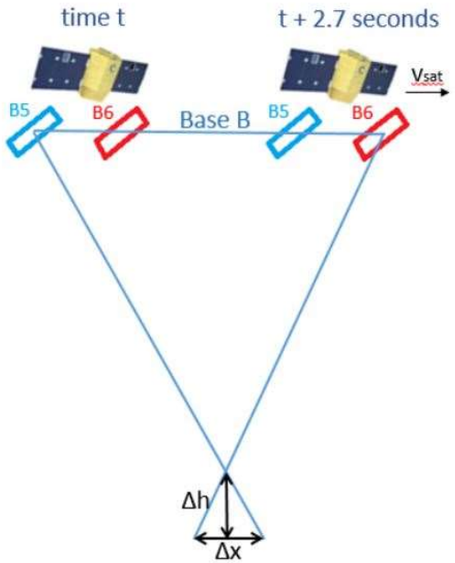
# Can we bring this to a more Sentinel 2 like satellite?

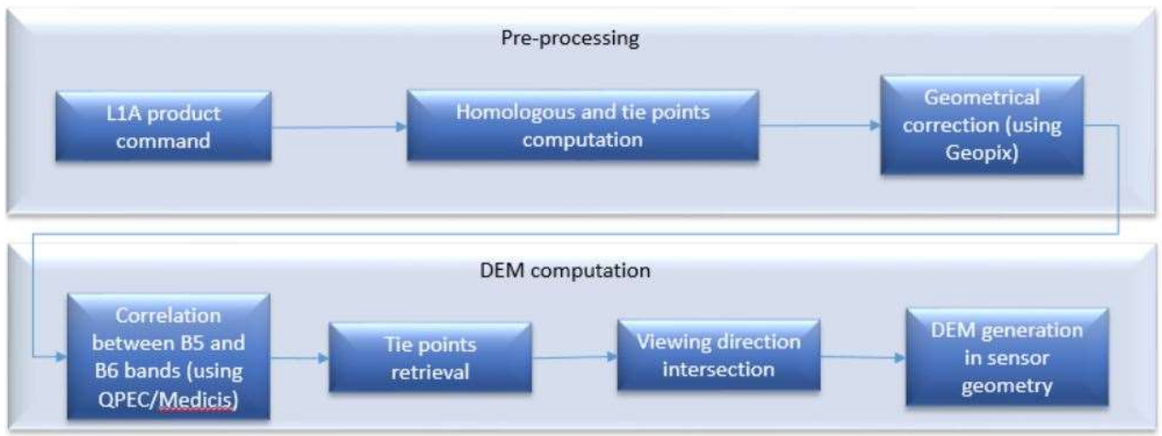
**Study site: Field Research Facility at Duck; NC, USA --- Bergsma et al., in review at RSE**



# Can we bring this to a more Sentinel 2 like satellite?

## VENµS Topography



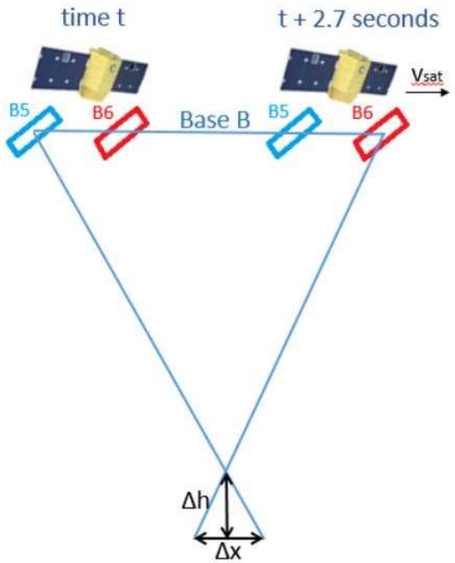

## VENµS bathymetry (wave kinematics)

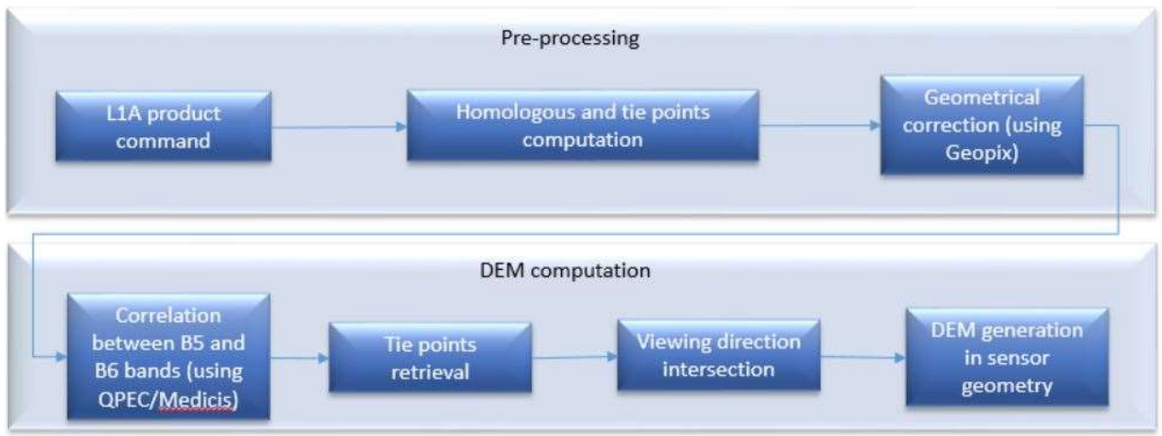
$$c = \frac{\Delta\Phi}{k\Delta t}$$

$$h = \frac{1}{k}\tanh^{-1}\left(\frac{c^2 k}{g}\right)$$

# Can we bring this to a more Sentinel 2 like satellite?

## VENµS Topography




## VENµS bathymetry (wave kinematics)

*Similar approach as presented in Bergsma et al., 2019.*

1. *Radon Transform*
2. *DFT analysis*

$$\tilde{H}(k) = \sum_{n=0}^{N-1} h_n(\rho) e^{-2\pi i k n/N}$$

3. *Phase shift calculations*

$$\Delta\Phi(k,\theta) = \tan^{-1}\left(\frac{\Im\left(\tilde{H}_{t+1}(k,\theta)\tilde{H}_t(k,\theta)^*\right)}{\Re\left(\tilde{H}_{t+1}(k,\theta)\tilde{H}_t(k,\theta)^*\right)}\right)$$

4. *Approximation of the celerity and depth:*

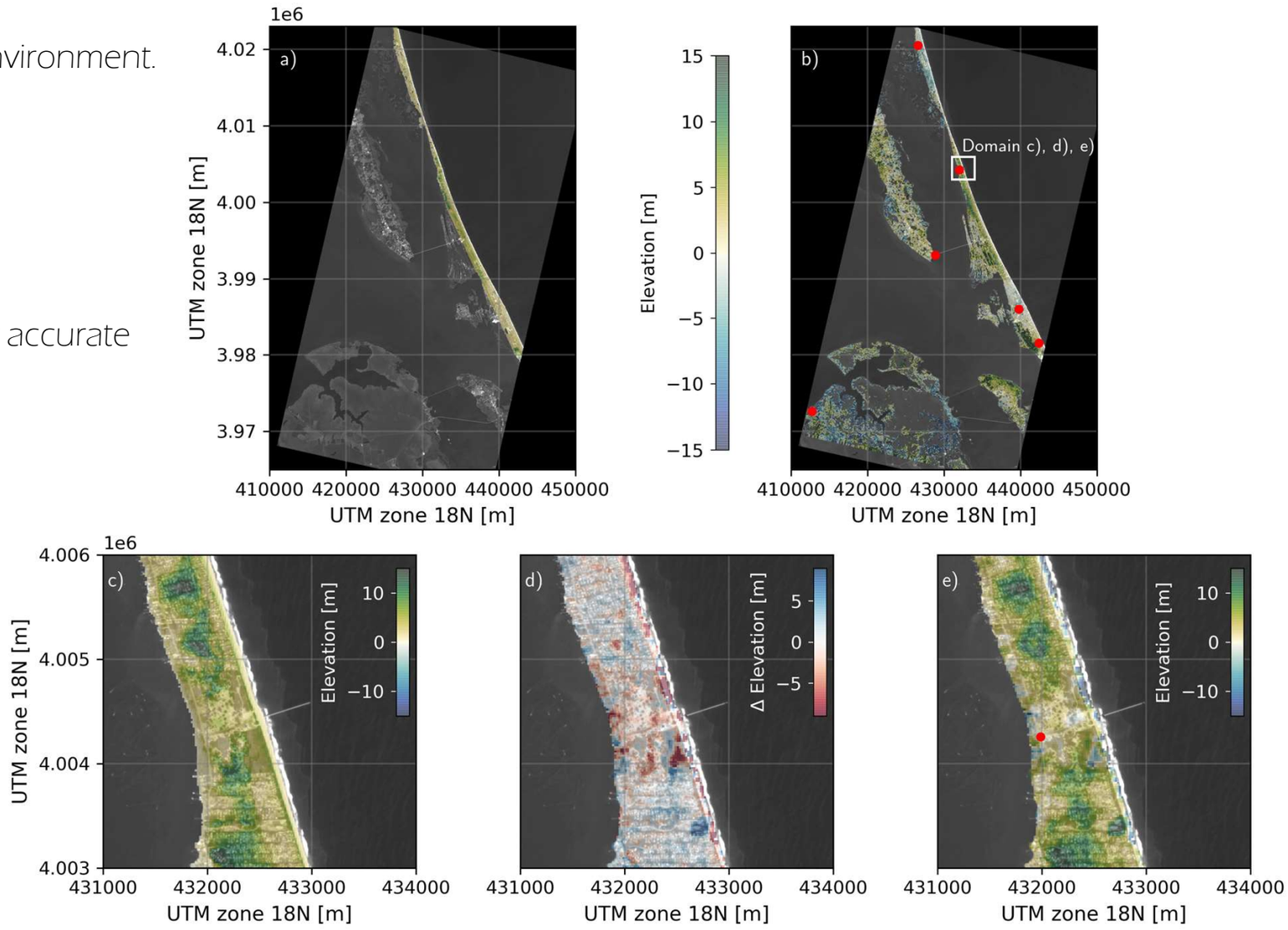
$$c = \frac{\Delta\Phi}{k\Delta t} \qquad h = \frac{1}{k}\tanh^{-1}\left(\frac{c^2 k}{g}\right)$$

# VENµS; Topography results

*Bergsma et al., in review at Remote Sensing of Environment.*

*Performance:*

- *Dune features are well represented*
- *Weak B/H ratio remains a great challenge for accurate topography estimations*
- *Error extremes around O(m).*

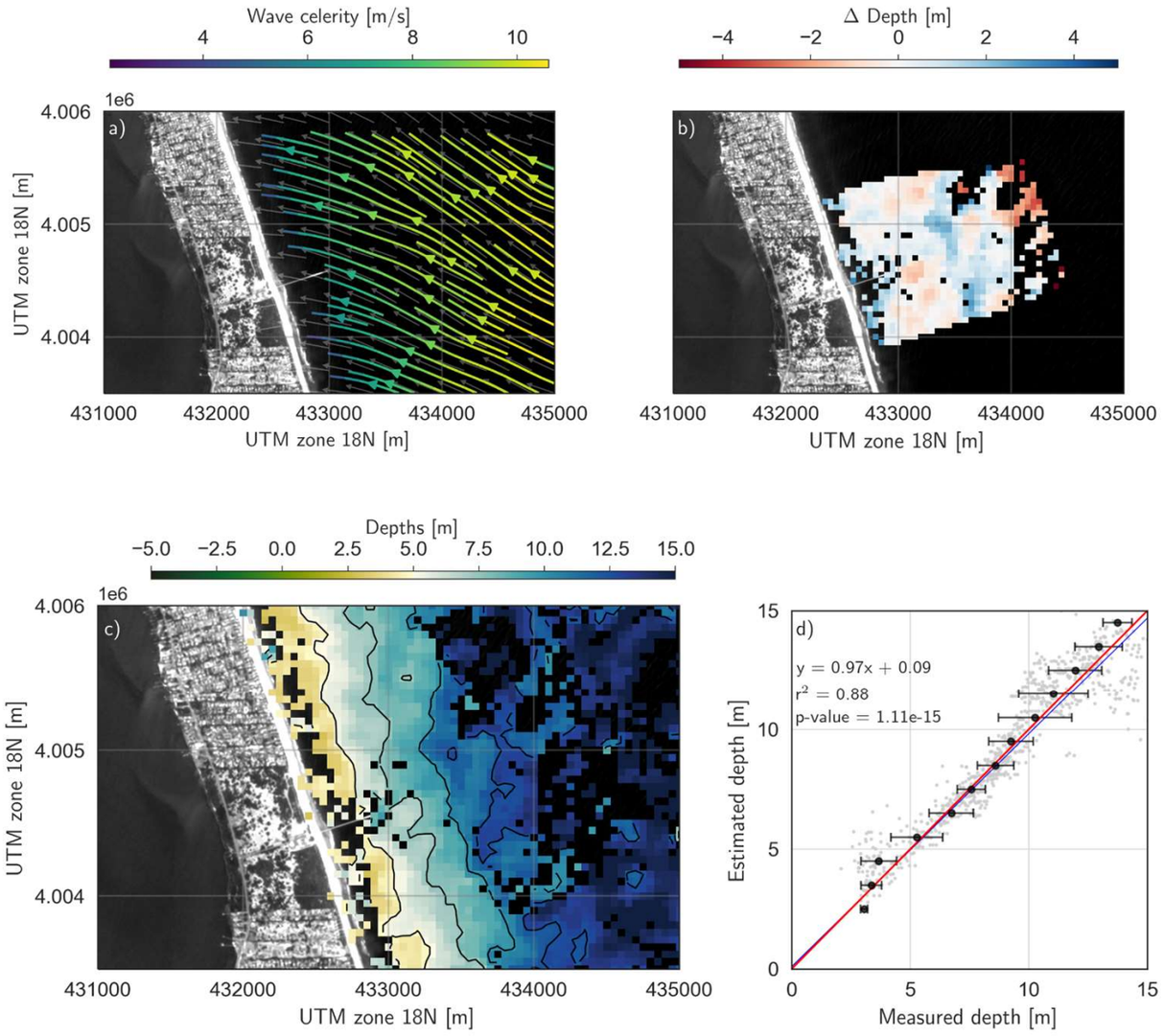


# VENµS; Bathymetry results

Bergsma et al., in review at Remote Sensing of Environment.

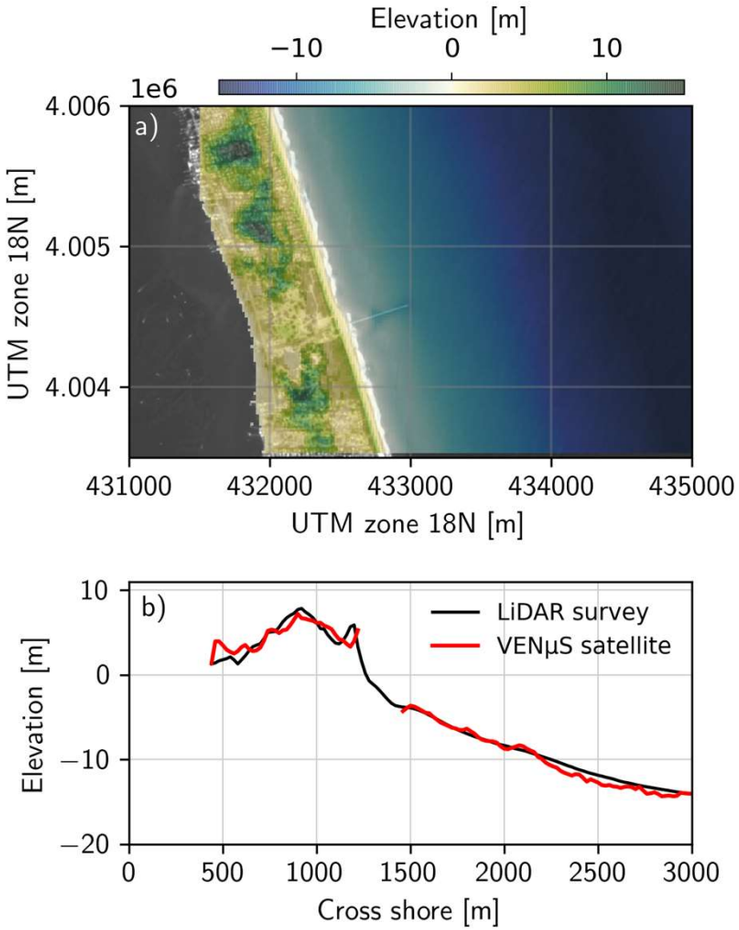
Performance:

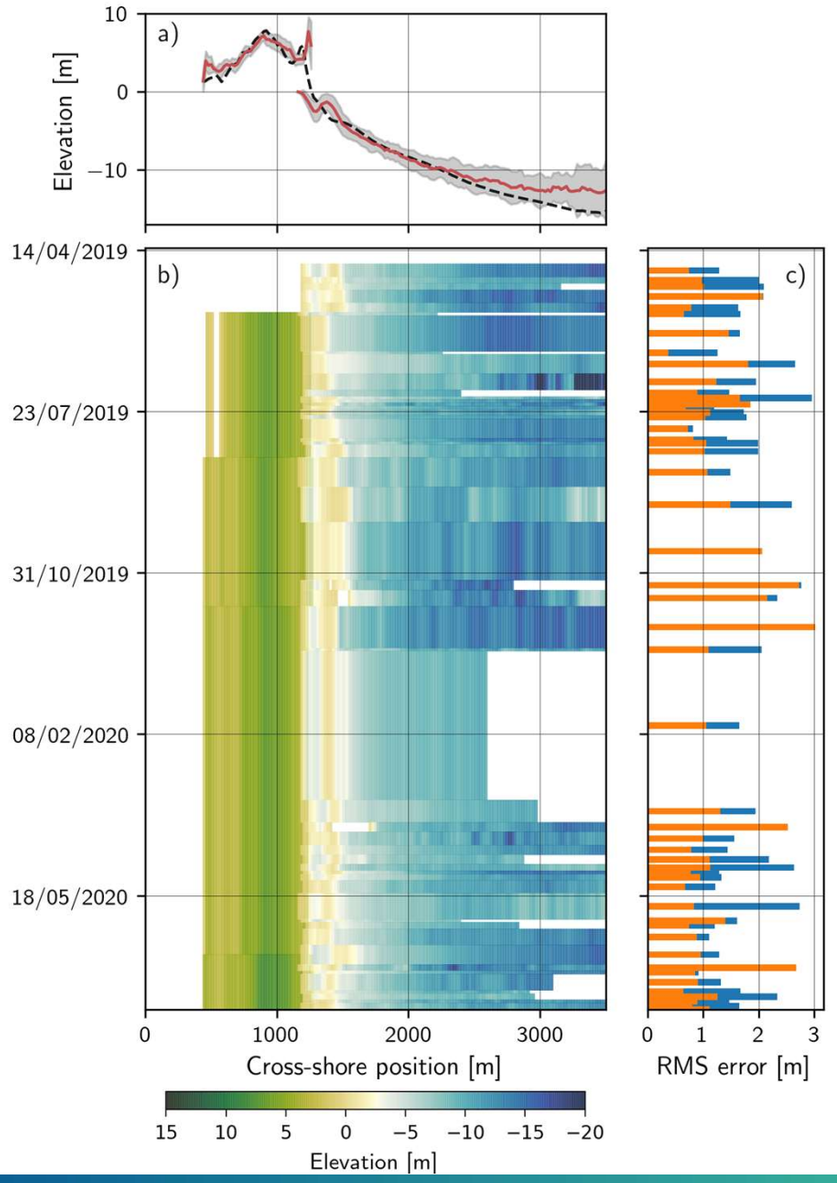
- Bathymetric features well resolved
- This particular case, 1,07m RMS error,
  Sub-metric RMS errors at best
- Independent from turbidity
- Challanges remain around the breaking zone and in the surfzone.



# VENµS; Continuum results and evolution

*Bergsma et al., in review at Remote Sensing of Environment.*



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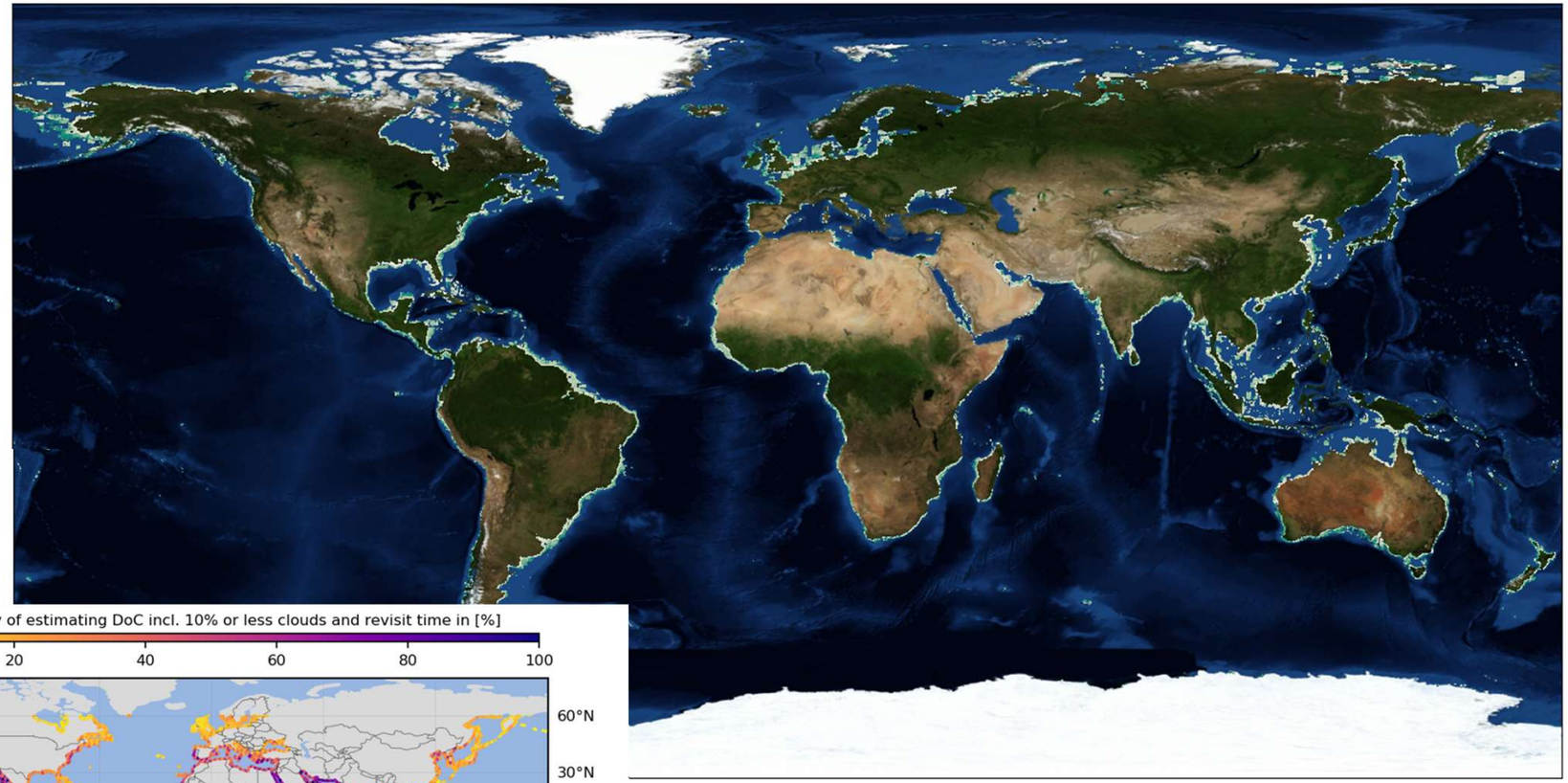
# BATHYMETRY AT REGIONAL SCALES

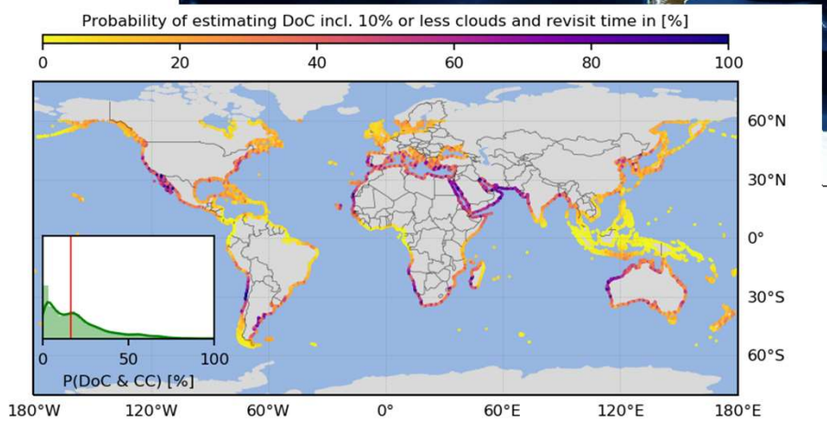
## TOWARDS ROUTINE MAPPING OF THE COASTAL ZONE

# Bathymetry at regional scales using Sentinel 2

*Large-scale implementation (CNES, IRD, SHOM) on the CNES HPC cluster, using S2Shores (Bergsma et al., 2019, 2021)*

*Almar et al., in preparation*

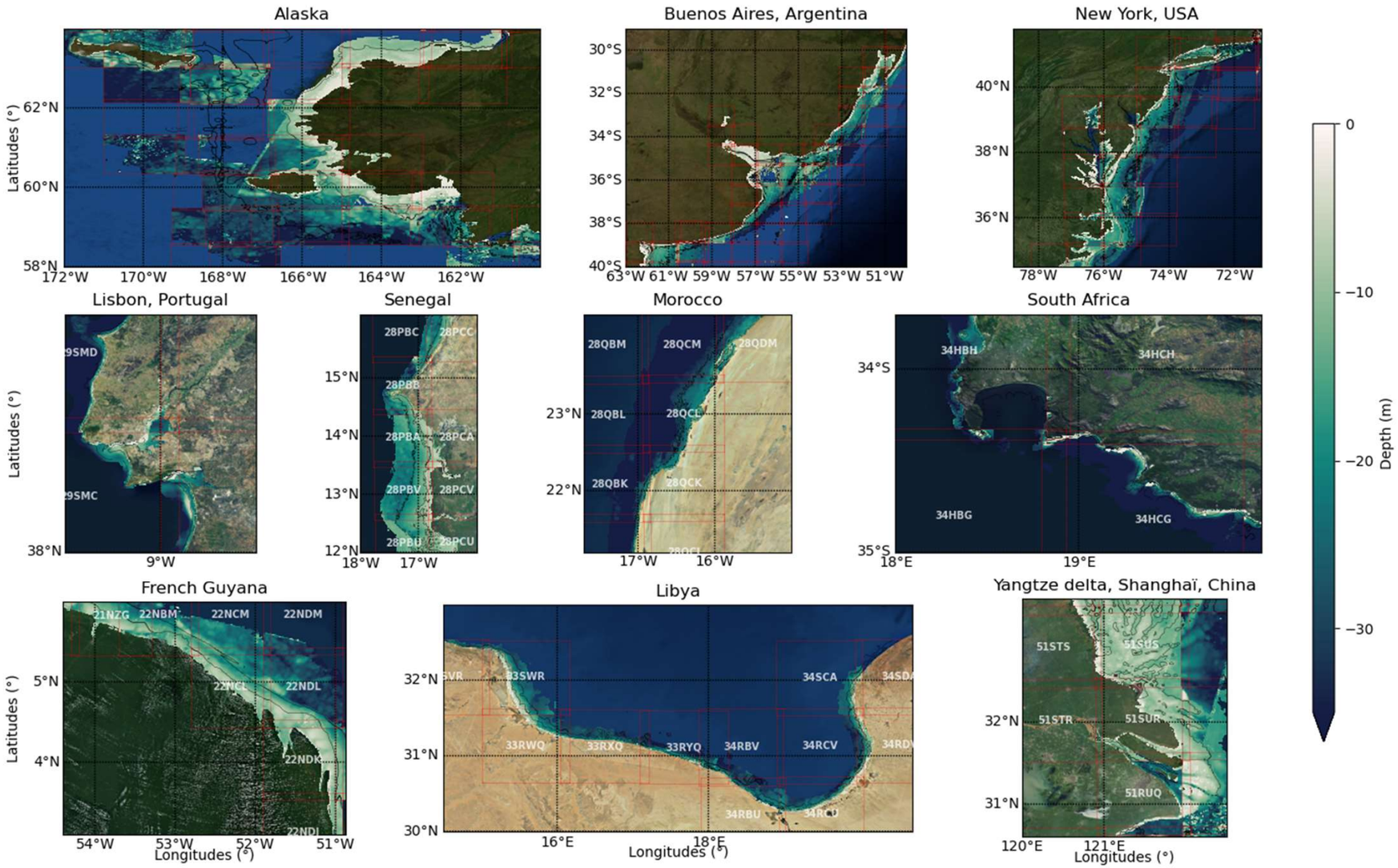



*Bergsma and Almar, 2020.*

# Bathymetry at regional scales using Sentinel 2

Selected hotspots:



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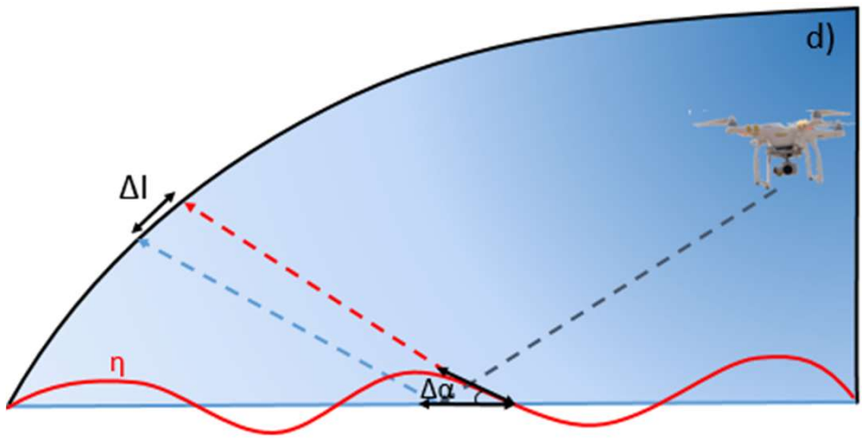
# SEA STATES USING OPTICAL SATELLITE IMAGERY

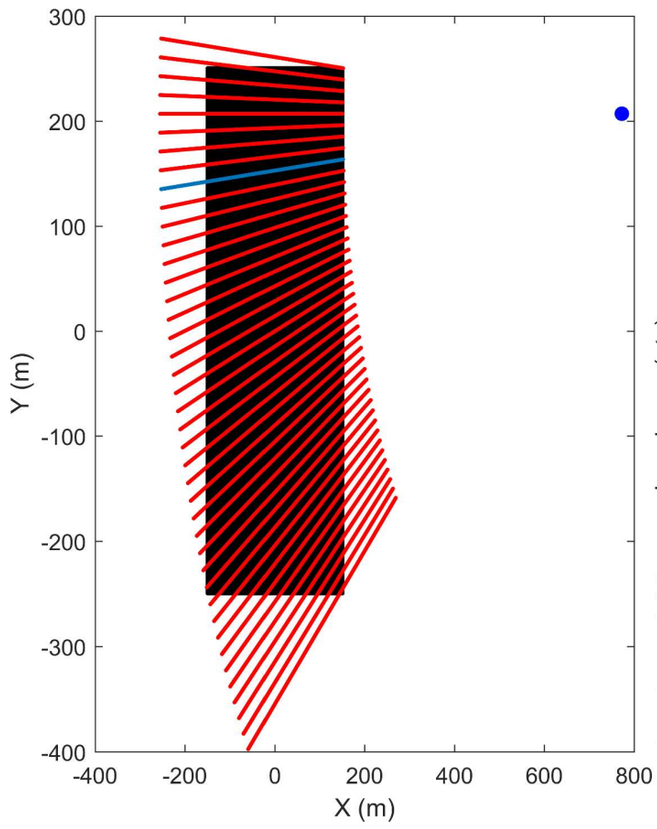
## ON-GOING WORK

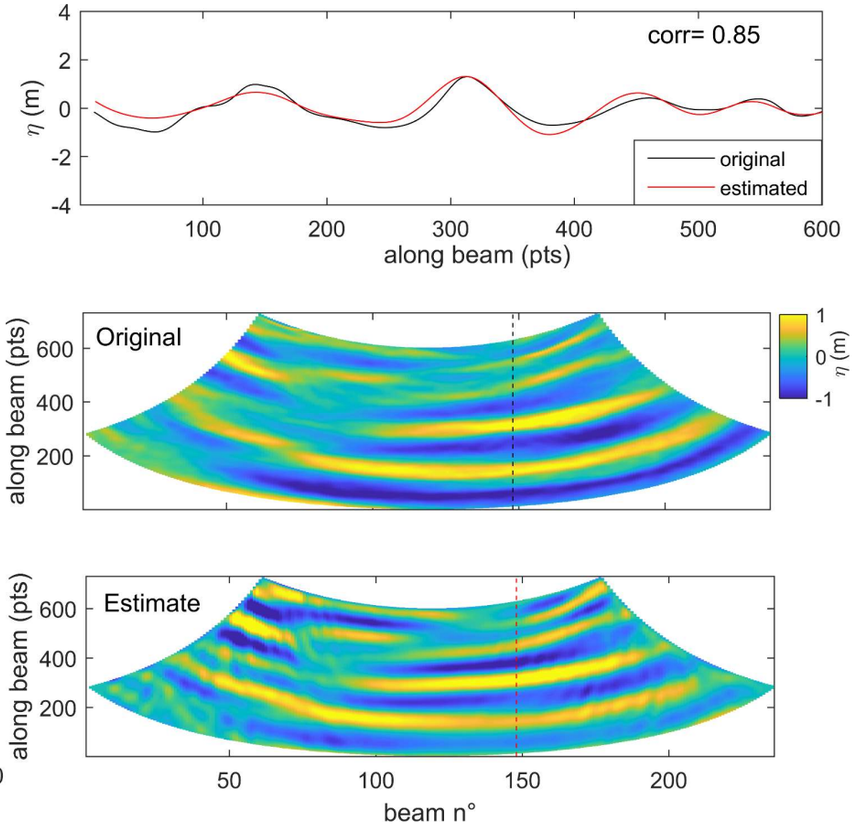
# Free-surface reconstruction with single images

*Almar et al., 2021*



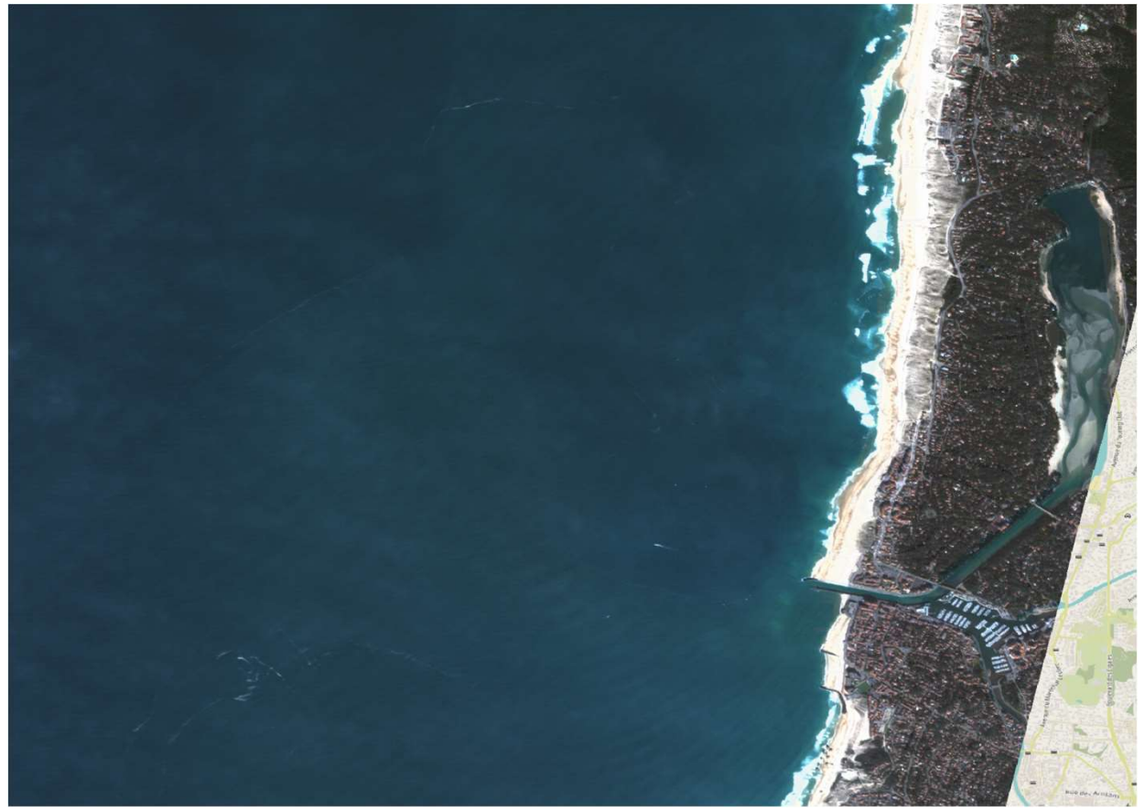

1. Sky reflection model
2. Local surface slope model
3. Integration over beams.

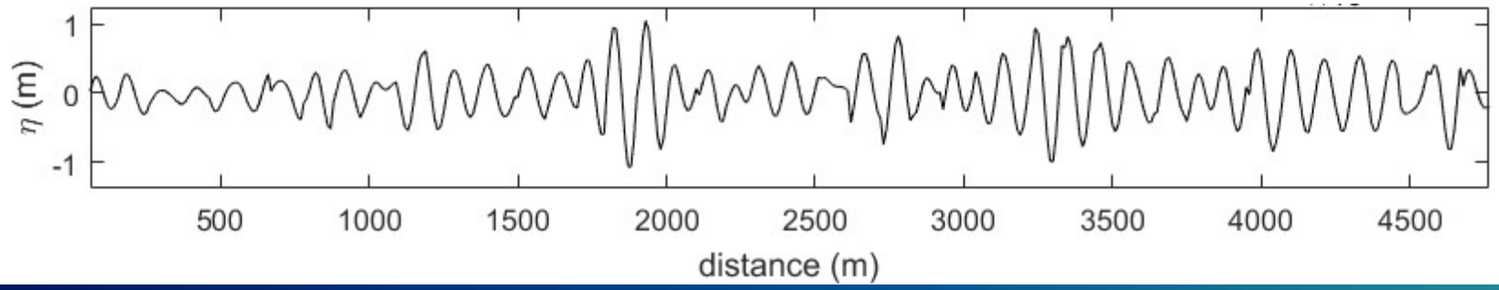


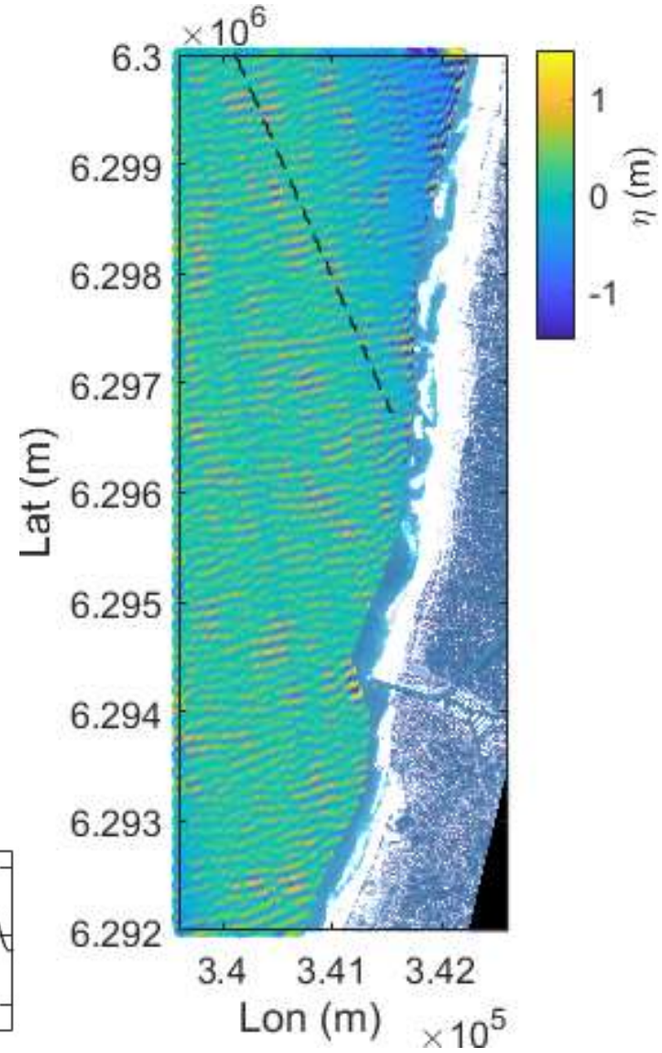



# Free-surface reconstruction with single images

Almar et al., 2021



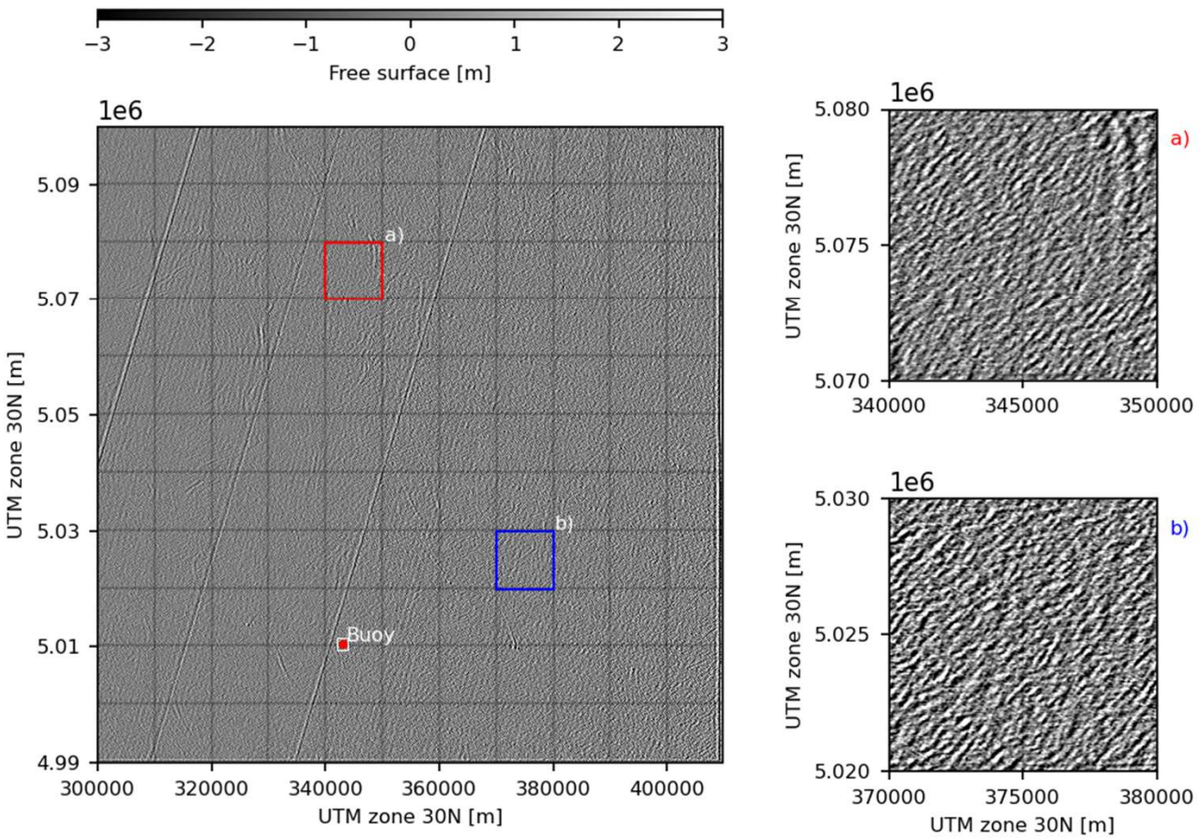


# Free-surface reconstruction with Sentinel 2 (on-going work)

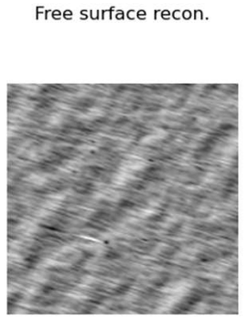
In cooperation with Ifremer (Bertrand Chapron / Guillaume Dodet), Dr. Fab and Meteo France (Lotfi Aouf / Alice Dalphinet)

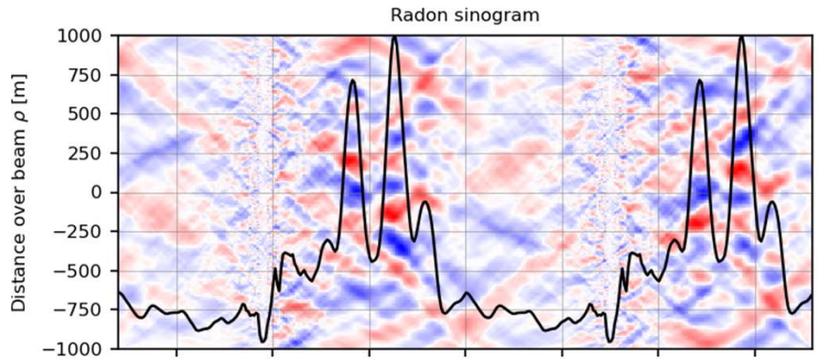
Bergsma et al, 2021 → Coastal Dynamics

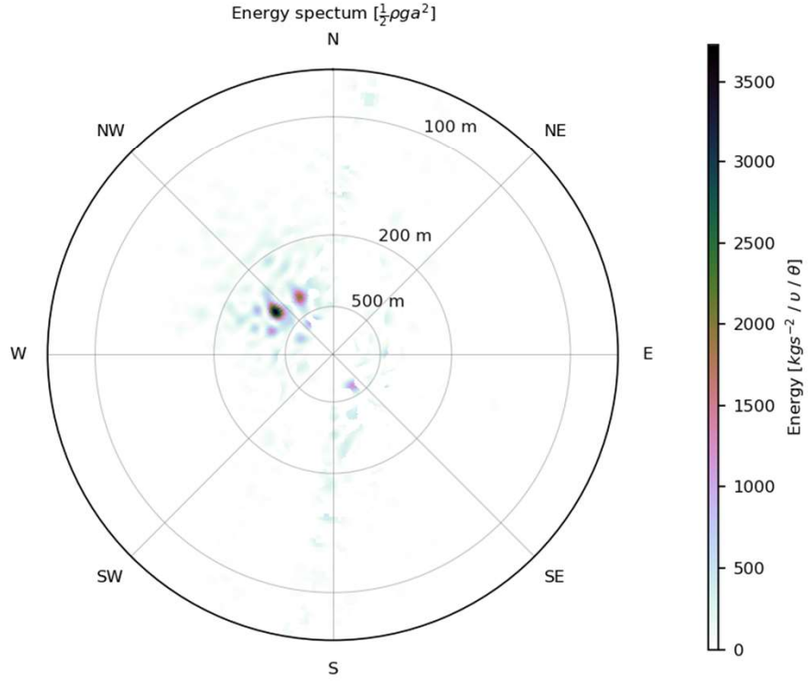








# Conclusion

- *We are working towards regular estimation of coastal topography and bathymetry using tailored and open-source satellite data*
- *Accurate topography estimations remain a tool for tailored satellite missions*
- *Accurate bathymetry estimation is possible with a wave-kinematics method, also in turbid waters*
- *First exploratory study show that regional (coastal) sea state estimation from optical satellite images is possible and can be done on a regular basis.*