# Satellite imagery for intelligent hydrographic planning

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BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

# Satellite-based operational planning in marine surveying

## Today: Fixed surveying schedule

(little adapted to local/temporal conditions)

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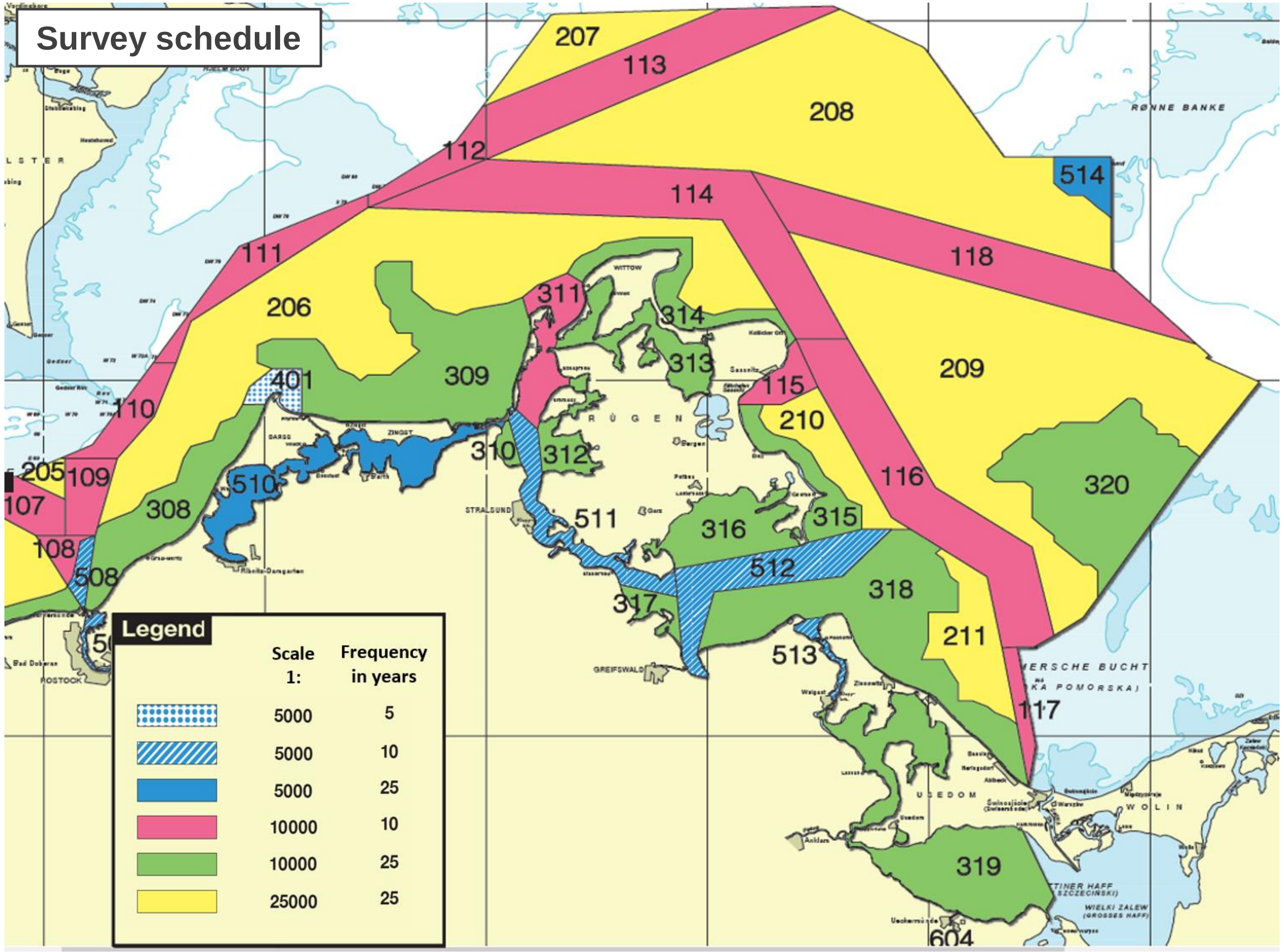
## Aim: Dynamic surveying schedule

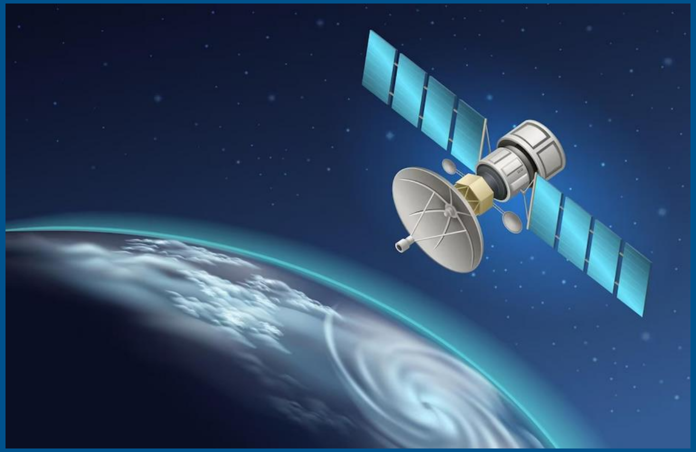
(regards small-scale conditions and temporal events)

## → R&D Project

(2022-2025)



# Structure of the operational service



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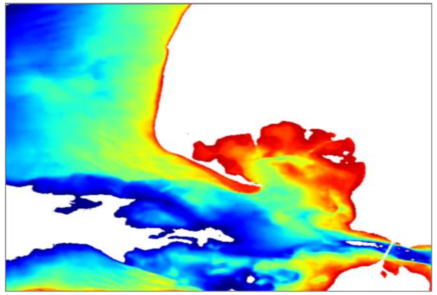
**Multispectral satellite imagery**
(e.g. Sentinel-2)



**AI-based bathymetric estimation**

## Change Analysis

(detection, quantification)

**Additional information of**

- wind (DWD)
- currents (BSH)
- wave height (Copernicus)
- crowdsourced bathymetry
- …

**Yes** → new prioritised surveying
**Maybe** → interactive review
**No** → no need for action

# Database

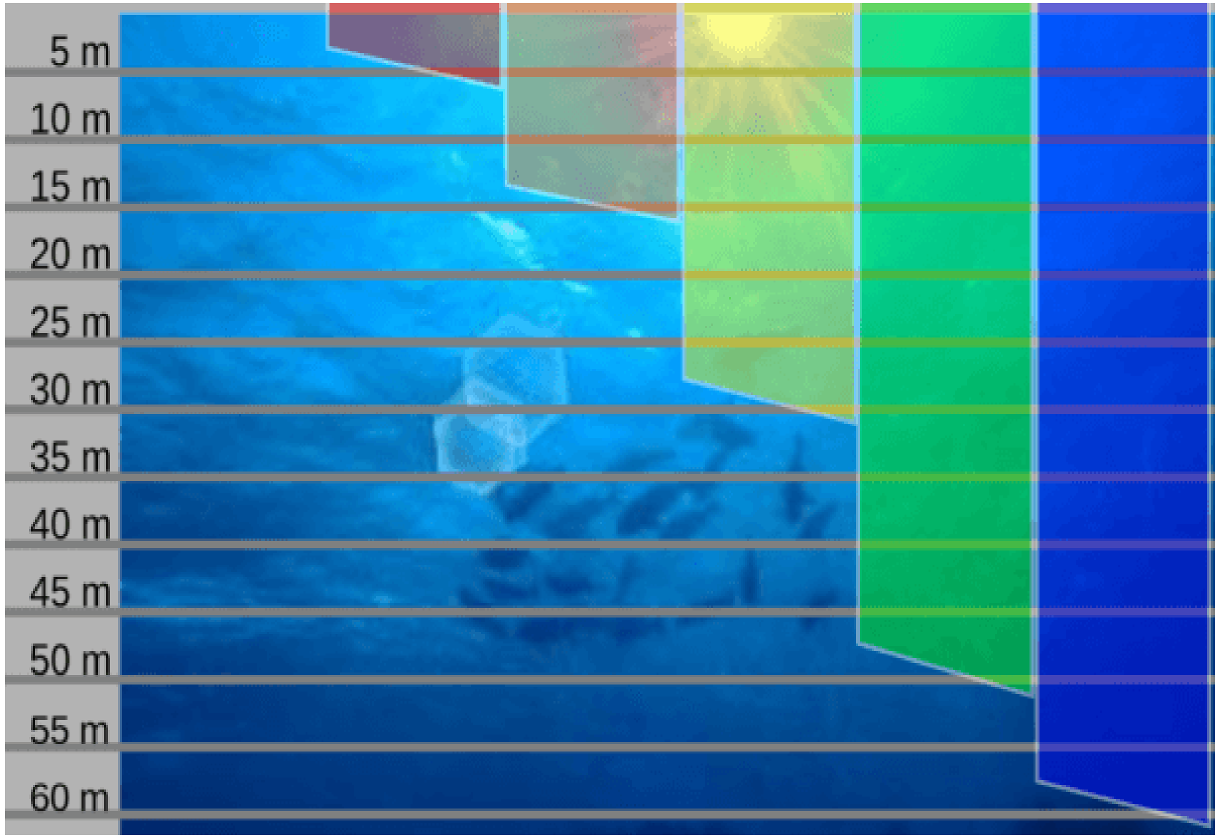
## Multispectral images (Sentinel 2)

- Sentinel-2
  - 10 m × 10 m resolution
  - 10 days revisit time
  - free of charge
- Limited to optically shallow waters (Baltic Sea ca. 10m)
- Challenges:
  - clouds
  - seabed cover
  - turbidity
  - …

# Physical background

## Underwater optics

### Penetration depth of light




Momchil (2019)

### Colour ratio correlates with water depth

M.H. Schleswig Germany (2021)

# Satellite-derived bathymetry (SDB)

## Empirical approach according to Stumpf et al. (2003)

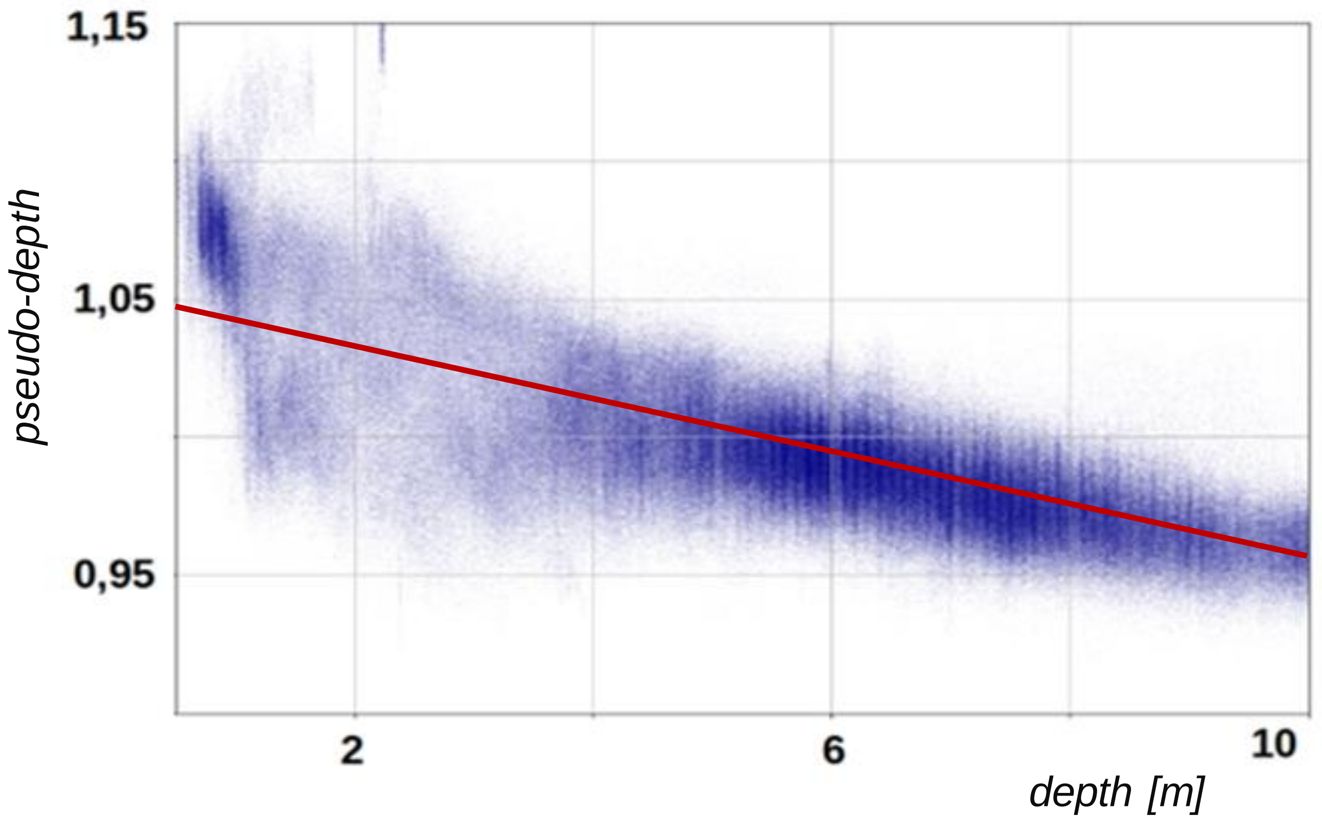
- Approximately linear behavior of the pseudo depth :

$$\text{pseudoDepth}_{BG} = \frac{ln(I_{blue})}{ln(I_{green})}$$

- Real depth with linear regression derivable:

$$\text{depth} = b_0 * \text{pseudoDepth}_{BG} - b_1$$

**Correlation of pseudo-depth with reference depth**

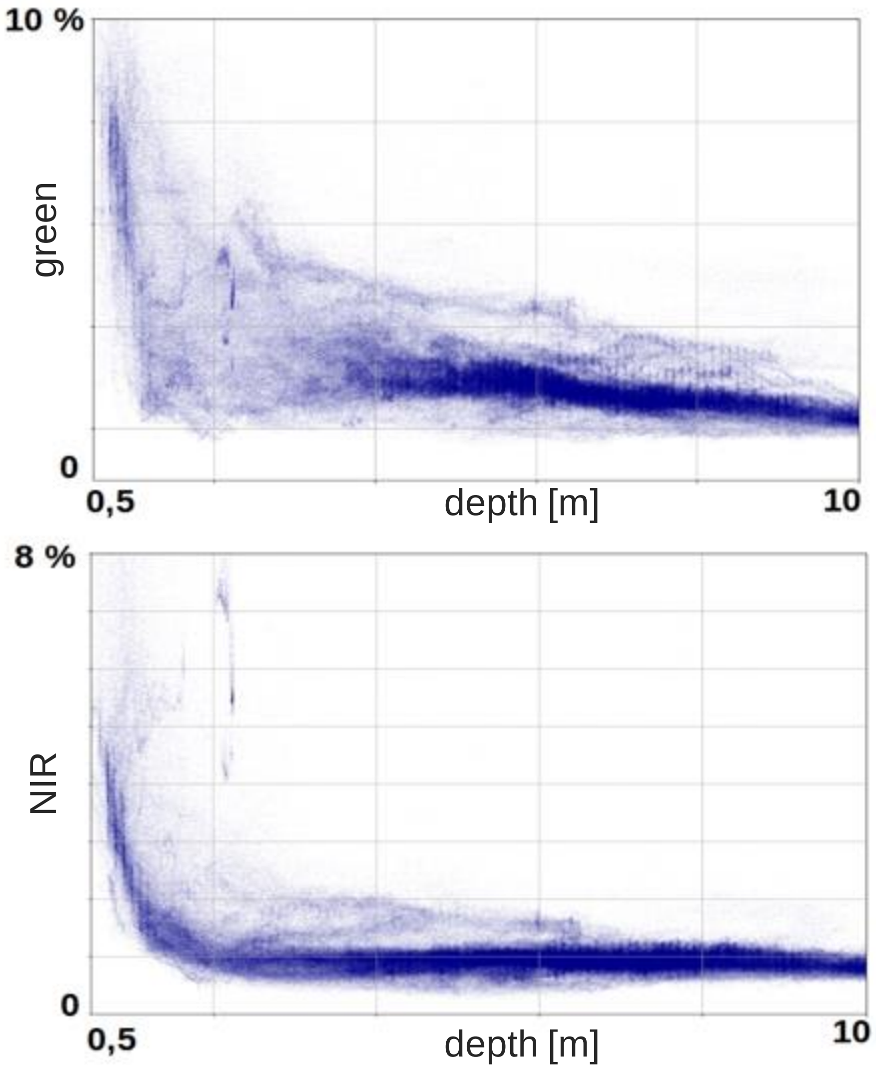


# Satellite-derived bathymetry (SDB)

## Integrating additional information

- Using additional Information
  - Colours (coastal-blue, blue, green, red, NIR)
  - Pseudo-depth (BG, BR, BNIR, GR…)
  - Turbidity information (NDTI, GNDVI, Hue-Angle)
  - Seafloor cover information
  - Distance to shore

→ Input for Convolutional Neural Network (CNN)



# Satellite-derived bathymetry (SDB)

## Convolutional Neural Networks (CNN)

**CNN-Regression:**

**Input**

*(Colours, colour ratios, turbidity…)*

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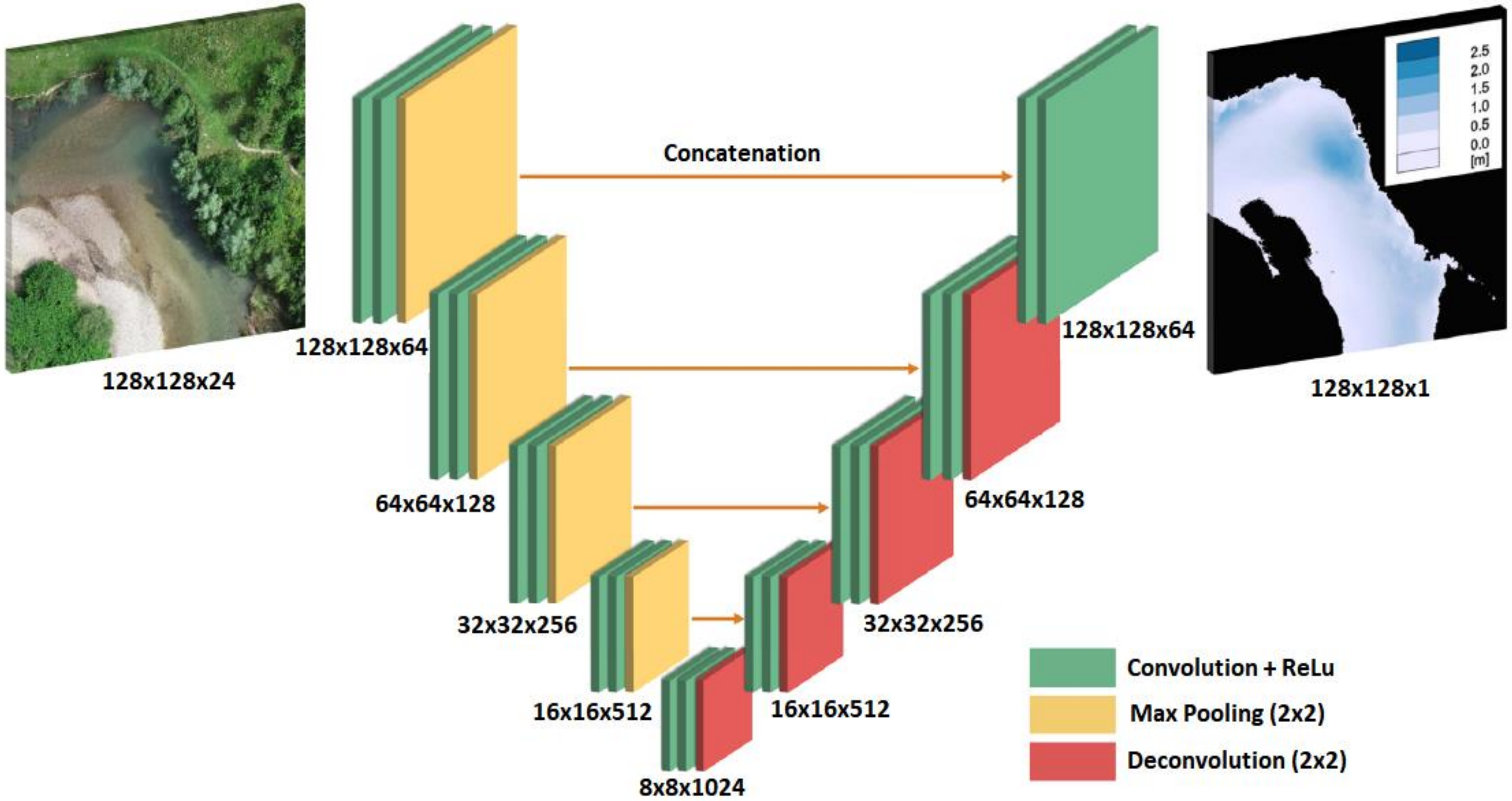
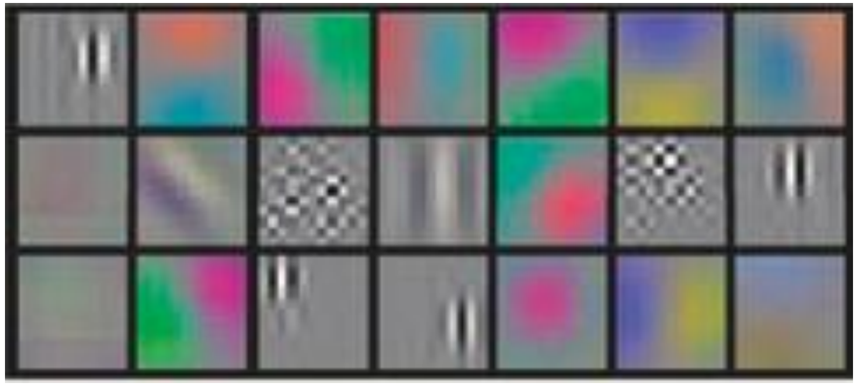
**Output:**

*(water depth)*

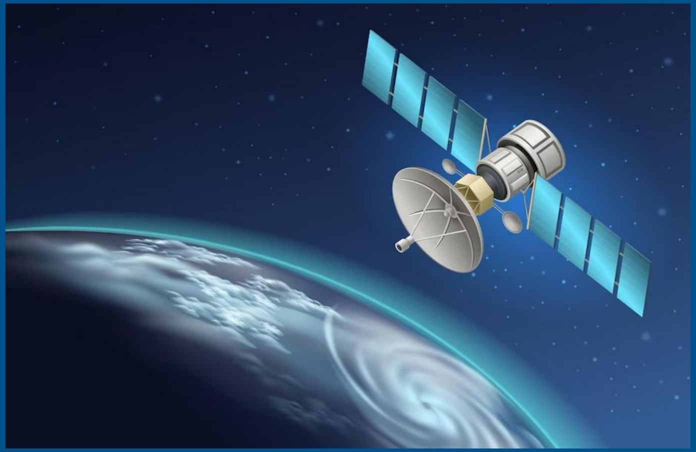

Mandlburger (2020)



Nishimoto (2018)

# Satellite-derived bathymetry (SDB)

## Prediction of water depths



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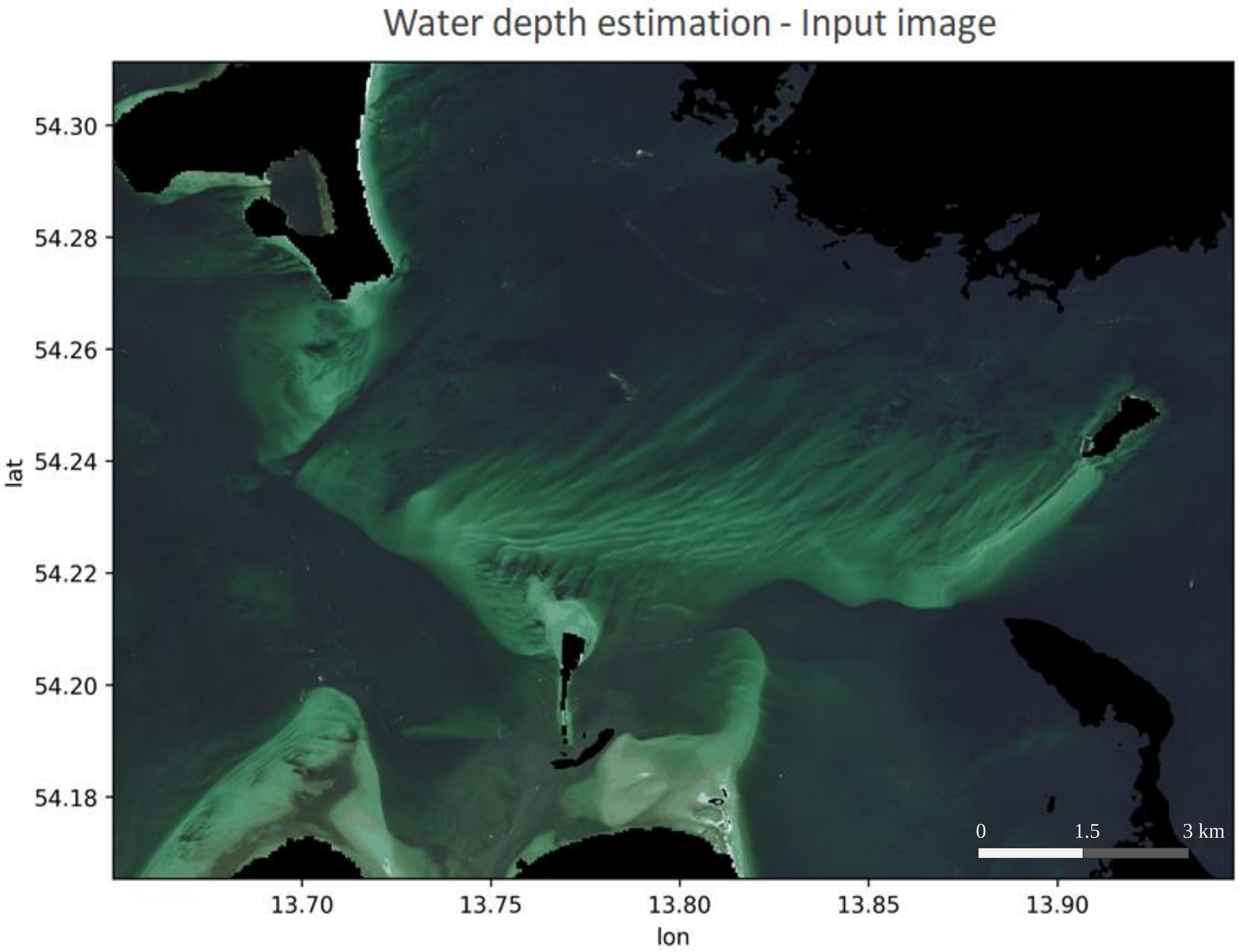
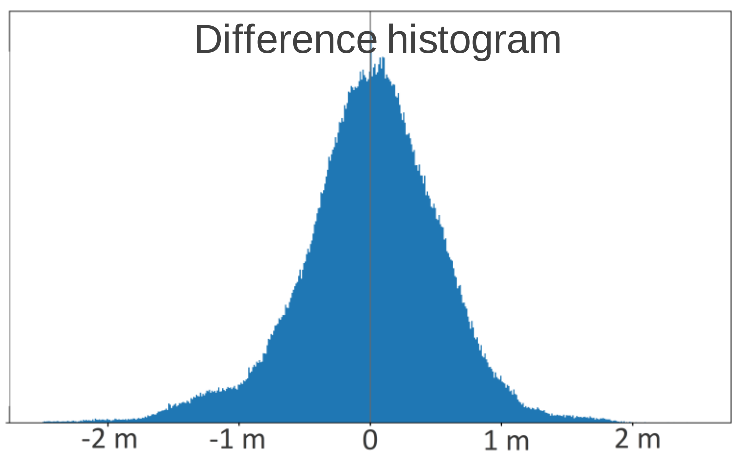
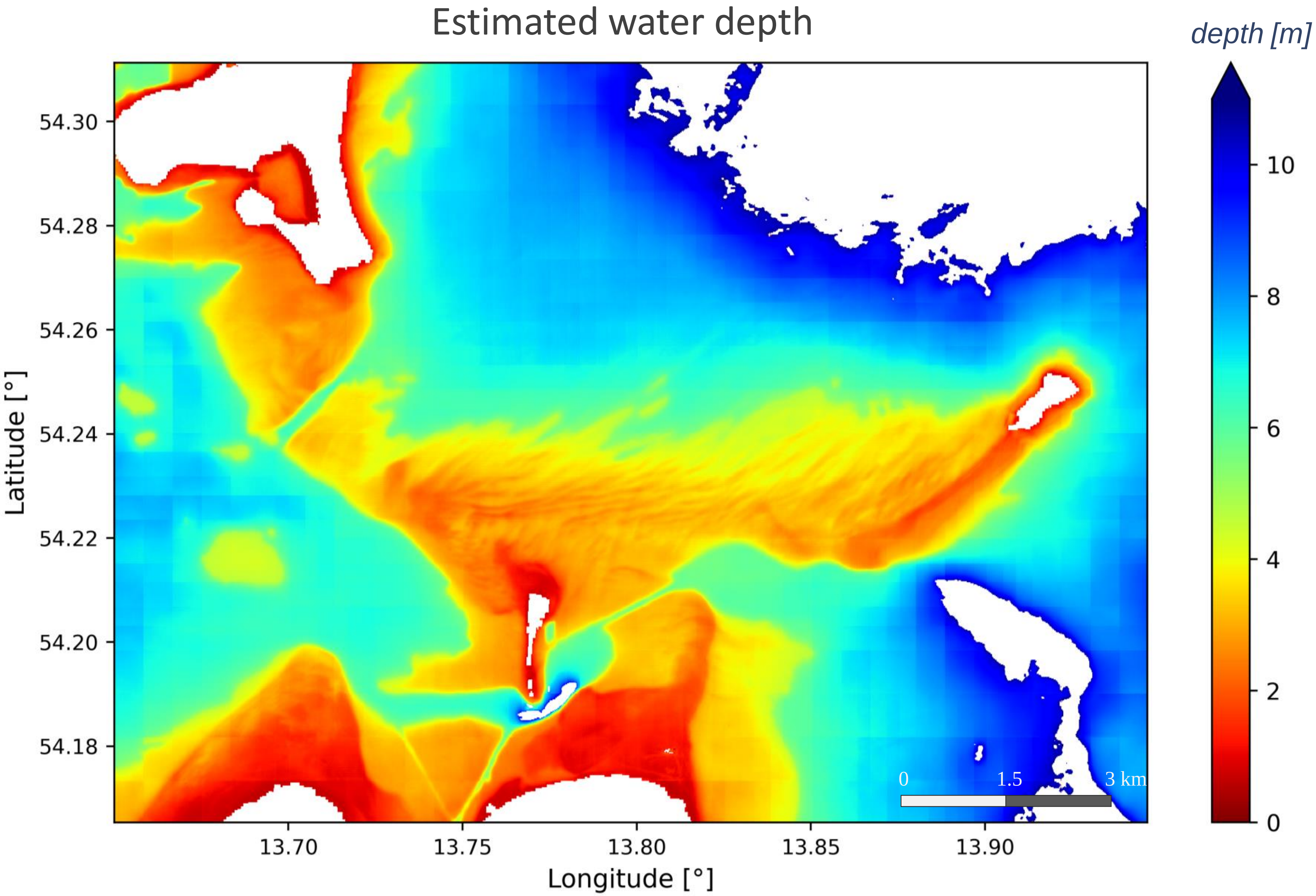


# Results of SDB

Results of an unknown scene in known area with good environmental conditions:

- RMSE: 86 cm
- MedAE: 47 cm
- 95% percentile: 1.74 m

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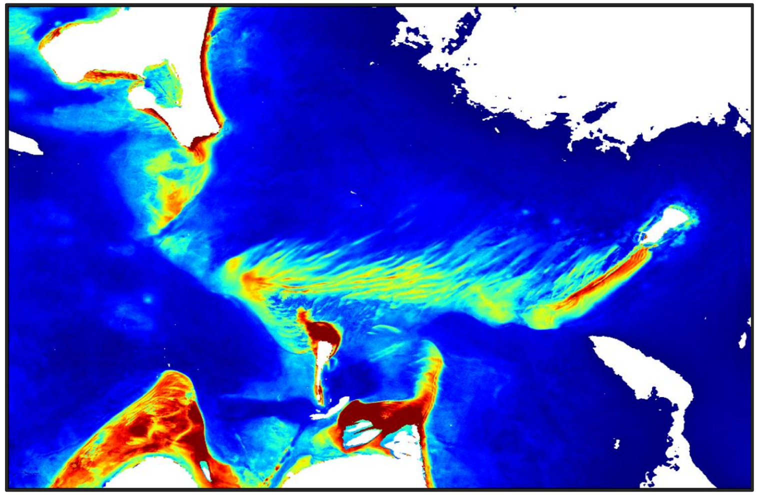
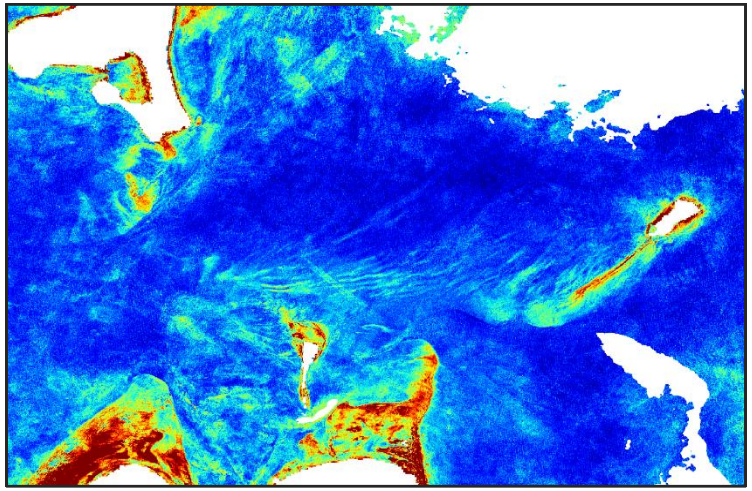
# Change Analysis

## Using different change detection methods

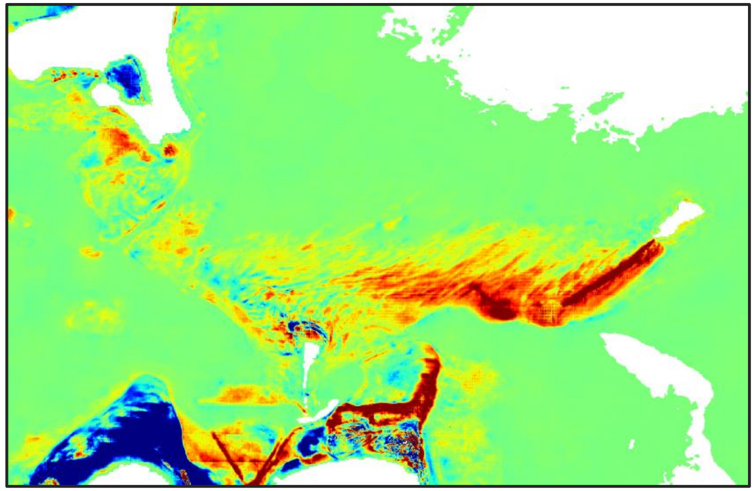
**Principle Component Analysis (PCA)**



**Change Vector Analysis (CVA)**



**Robust median differencing**



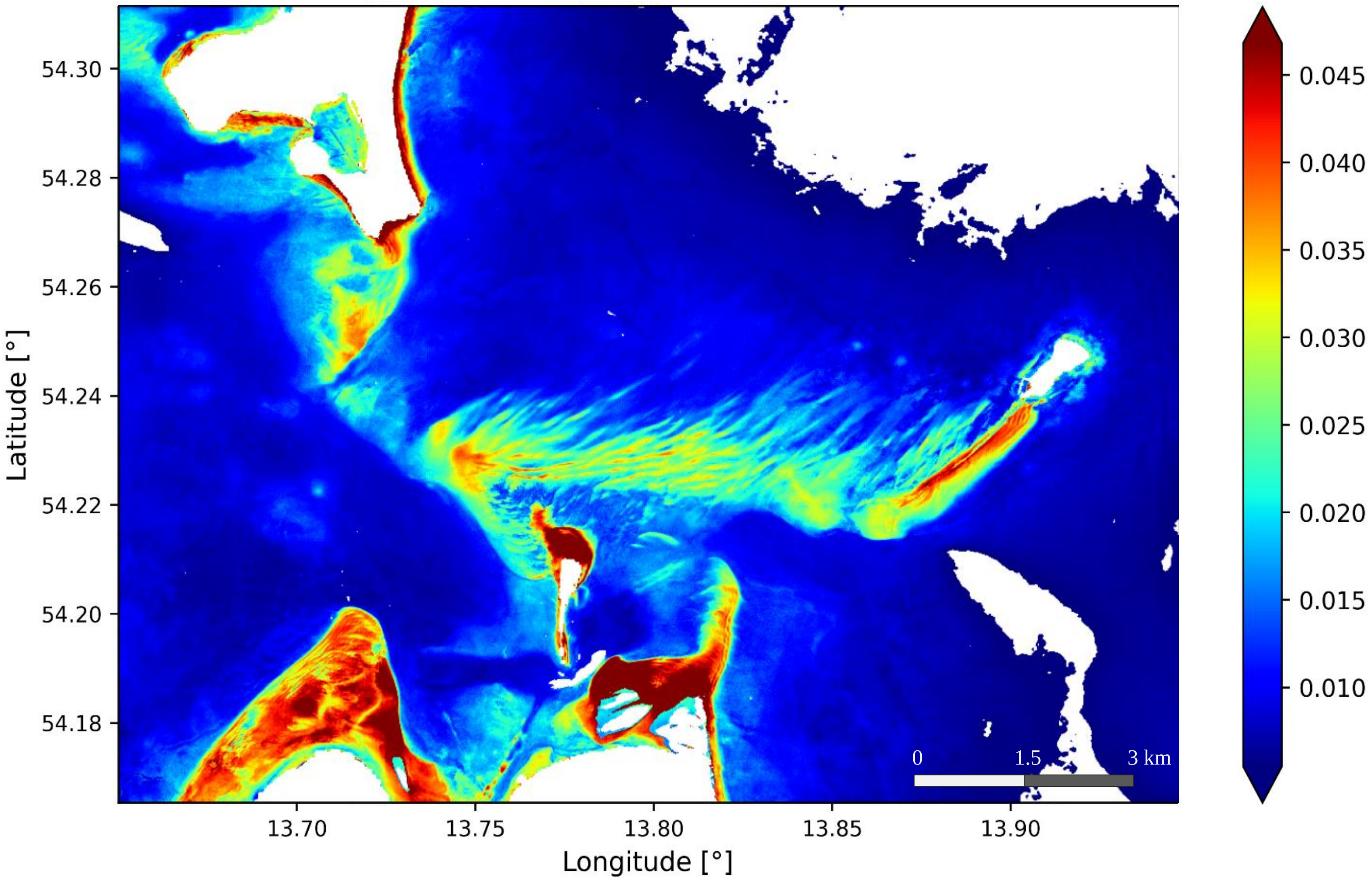
**Weighted sum**

# Change Analysis

## Principle Component Analysis (PCA)

- Compression methods (store max. information in fewer bands)
- Time-series: good representation of static areas, worse representation of dynamic areas
- Figure shows difference to „mean“ image

PCA – Median difference to reconstructed image

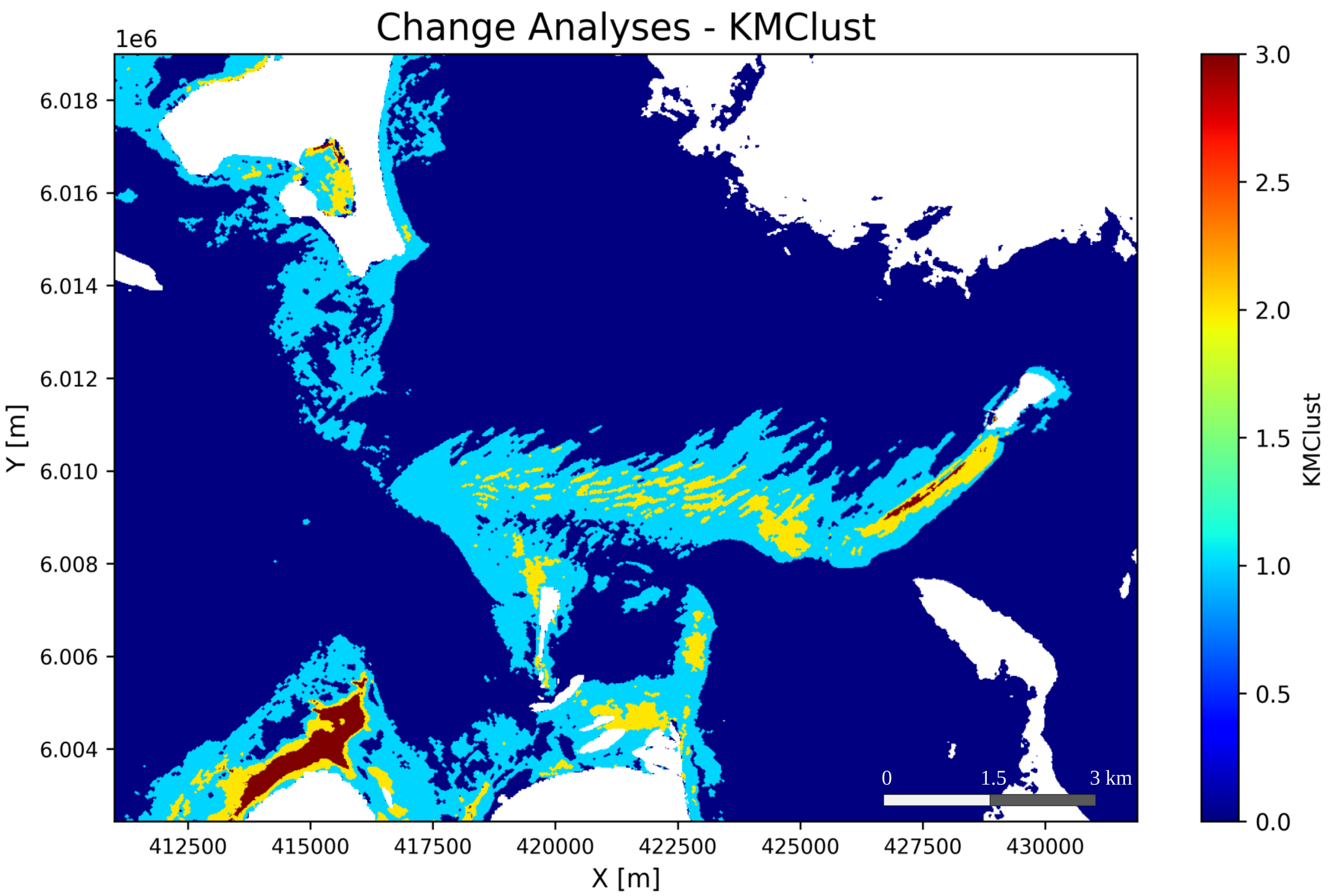


# Change Analysis

## Summation and Clustering

- Weighted sum of the normalised results of each change detection method
- Clustering according to intensity of summed change value

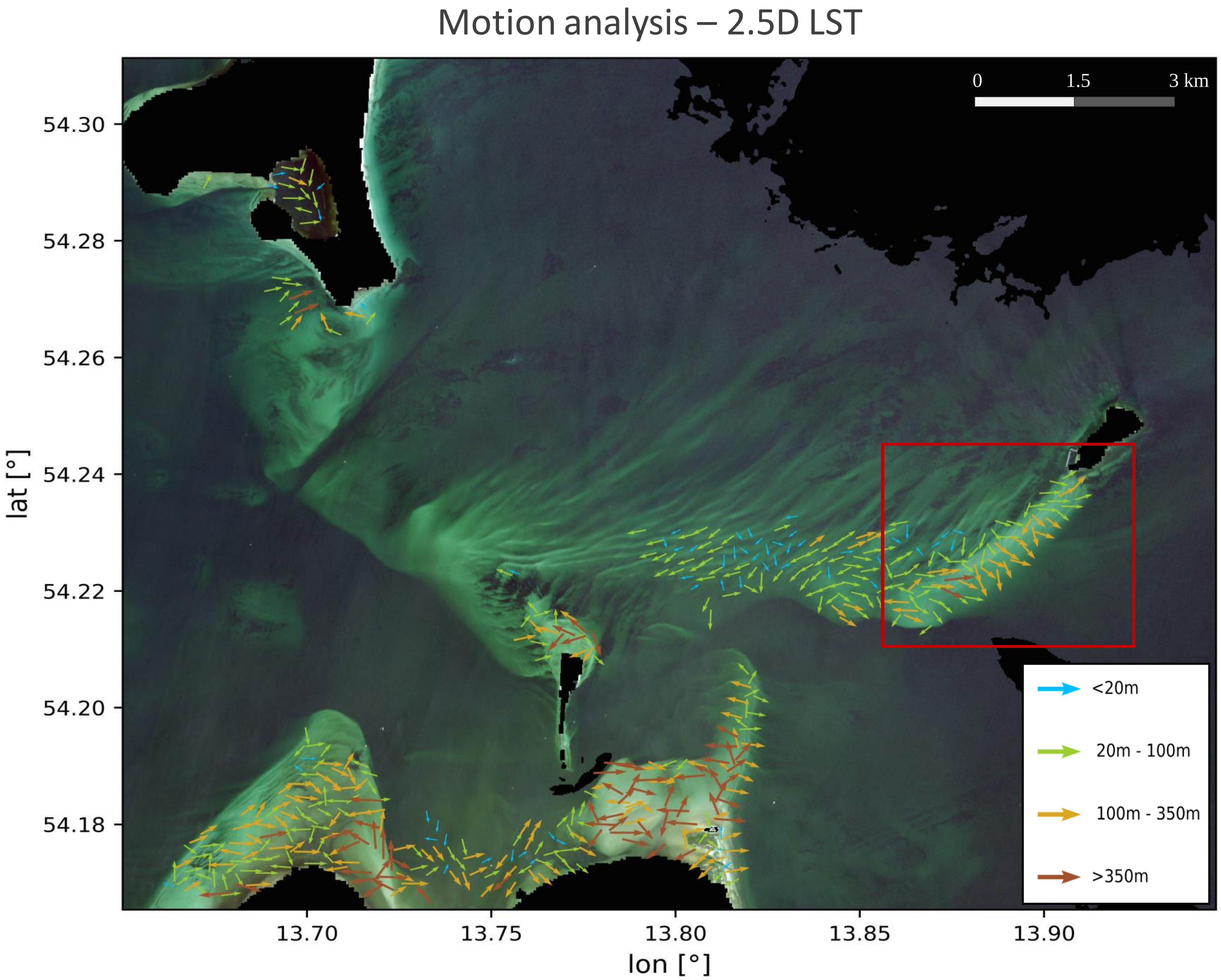
  → traffic light scheme



# Change Analysis

## Motion analysis

- Tracking-algorithm 2.5D LST
- Seeking best match of point patch between two images
- Combines colour and depth information
- Calculated motion direction and amount

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# Change Analysis

## Motion analysis

- Tracking-algorithm 2.5D LST
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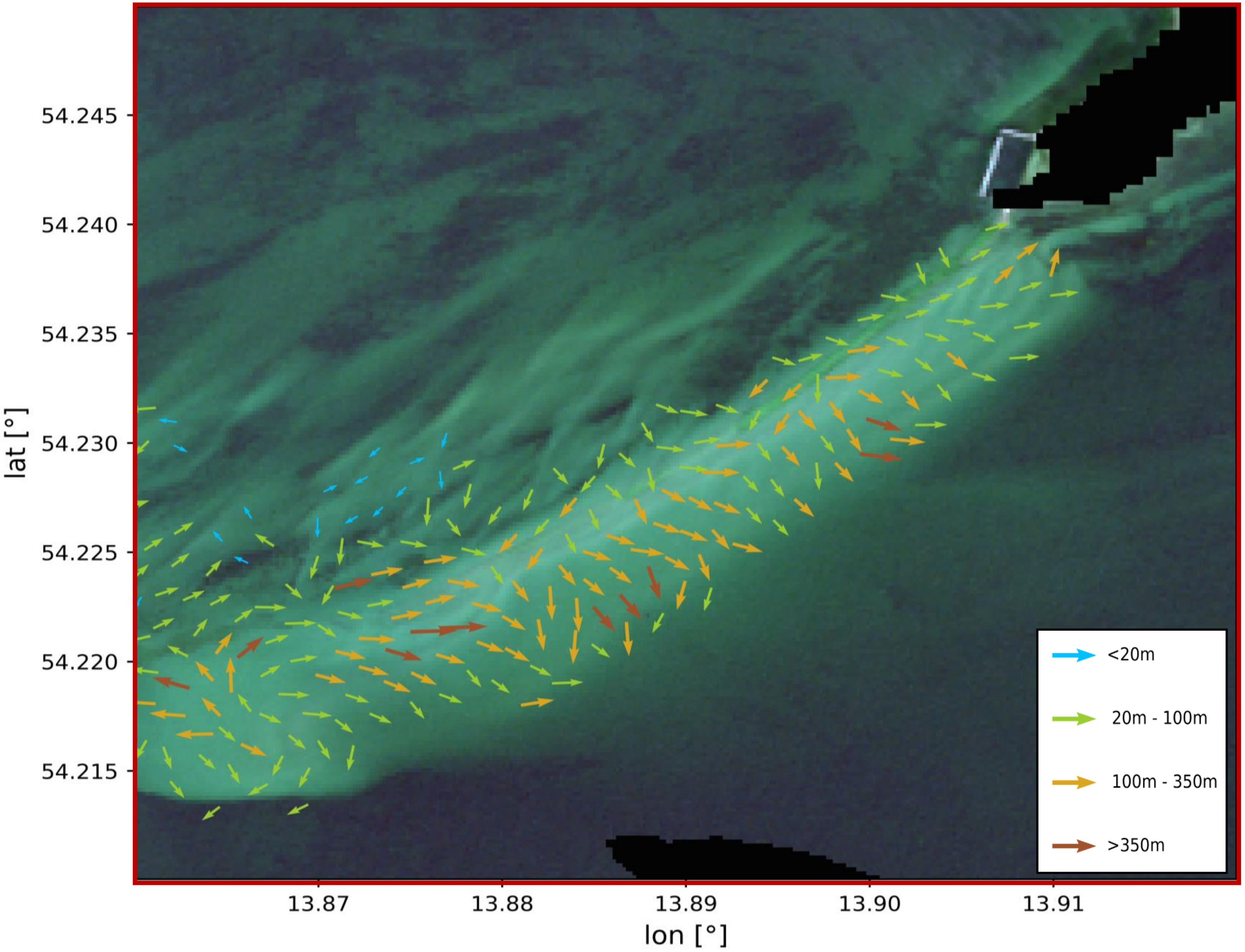
Motion analysis – 2.5D LST

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# Summary and outlook

- **Summary**
  - Algorithms and processing chain largely finalised
  - Service is operational (as prototype)

- **Outlook**
  - Improve CNN and bathymetric results
  - Improvement of weighting sum
  - Optimise clustering
  - Increase robustness and reliability

# Thank you for your attention!


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