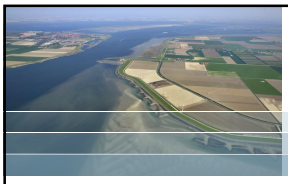

Deltares
Enabling Delta Life

Estimation of bathymetries from remote-sensed images for real-time forecasting

Leo Sembiring, Ap van Dongeren, Gundula Winter, Maarten van Ormondt, Christophe Briere, Dano Roelvink

Introduction

Background

- Underlying bathymetry is important for real-time hydrodynamic forecasting (e.g. Rip currents) or morphodynamic forecasting (e.g. Storm erosion)
- Bathymetry expensive to obtain with traditional methods

Objective

- Provide reliable and up-to-date nearshore bathymetry for real-time forecasting

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Contents

- Remote sensed video data
- Nearshore bathymetry from video data
- Application: Egmond aan Zee
- Conclusion and Further Improvement

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Remote sensed video data

Argus station

- Need for monitoring information at time scales of days to weeks and space scales of meters to kilometers.
- Expensive and not efficient with traditional monitoring techniques.

Nipius, 2002

➡ *(Argus) video monitoring!*

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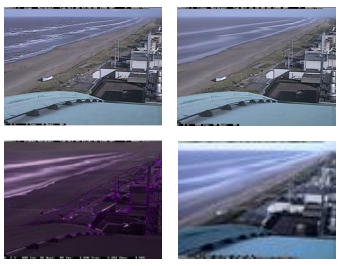
Remote sensed video data

Argus station

Standard data collection:

- 3 different images sampled every hour (snap shot, time exposure and variance image)
- 1 day-averaged image (daytimex, after post-processing)



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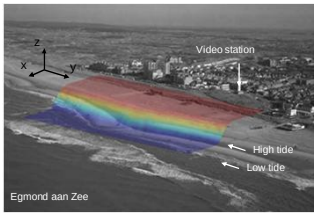
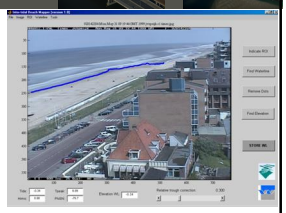
Remote sensed video data

Argus station

Intertidal bathymetry

"Intertidal Beach Mapper"





Multiple Shorelines over tidal cycle

⇩

Intertidal beach bathymetry

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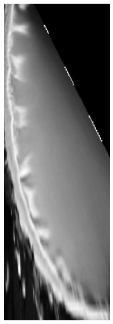
Nearshore bathymetry from video data

Beach Wizard concept (van Dongeren et.al 2008)

Argus video



Wave model

Time-averaged video observations vs. model simulations of breaking waves at Palm Beach, Australia (after: Reniers et al., 2001)

Update beach bathymetry through assimilation of video-observed and model-predicted patterns of wave dissipation

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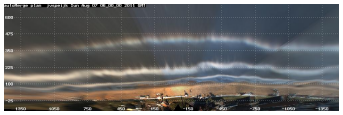
Nearshore bathymetry from video data

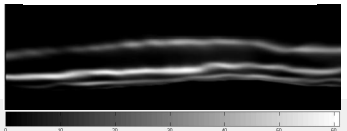
Beach Wizard concept (van Dongeren et.al 2008)

Wave dissipation maps from video



Plan-view merge timex images from 5 camera in Egmond

$$D(x,y) = \left(\frac{I_p(x,y)}{\int\int I_p dx dy}\right) \int E c_g cos\theta dy$$



Corrected intensity map after scaling with incoming energy flux

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Nearshore bathymetry from video data

Beach Wizard concept (van Dongeren et.al 2008)

Formulation

$$h(t+\Delta t) = h(t) + \alpha\left(h_{obs} - h(t)\right)$$

$$h(t+\Delta t) = h(t) - \alpha \sum_{i=1}^{6} \frac{\frac{df_i}{dh}}{\left(\frac{df_i}{dh}\right)^2 + \delta_i^2}\left(f_i - f_{i,obs}\right)$$

- Weighting factor α = 0 … 1 to account for uncertainties in the 'observation'
- No direct observation of depth, but derived from intensity which is a function of depth
- Use of multiple sources (next to pixel intensity) is possible

➡ *morphology not based on sediment transport*

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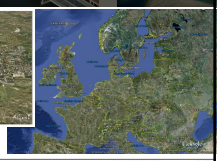
Application

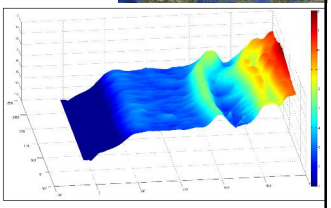
Rip current modeling and nearshore bathymetry from video data

Site : Egmond aan Zee
Five Argus video cameras
Field campaign : 22 Aug-26 Aug 2011



GPS bathymetry survey:

- Barred beach
- Inner bar rhythmic, interrupted by channels



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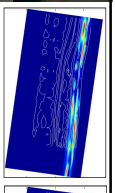
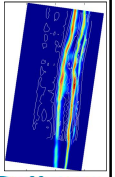
Application: Bathymetry estimation

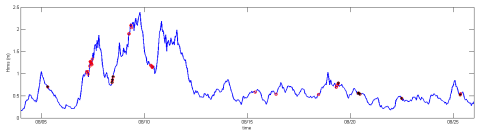
Rip current modeling and nearshore bathymetry from video data

Video data

- Wave dissipation maps from video : 37 maps
- Period of maps : 5 Aug – 25 Aug
- Maps show breaking signal at the outer bar (right bottom) and at the inner bar (right top)







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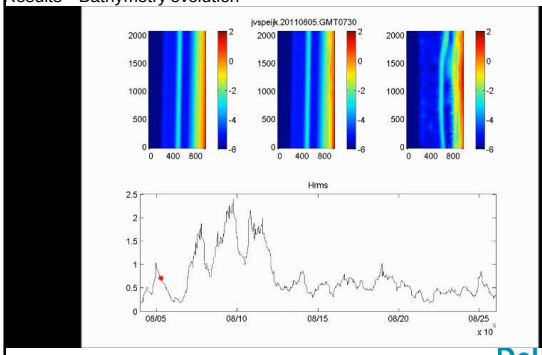
Application: Bathymetry estimation

Rip current modeling and nearshore bathymetry from video data

Results – Bathymetry evolution



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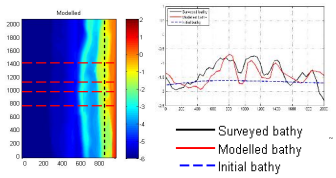
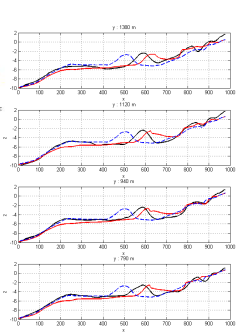
Application: Rip current forecasting

Rip current modeling and nearshore bathymetry from video data





- Bathymetry slowly converge to 'true bathymetry'
- Outer bar is shifted shoreward
- Bathymetry nearshore is reproduced well
- Rip channel patterns appear clearly
- Underestimates depth for troughs
- Bar 's crest offset

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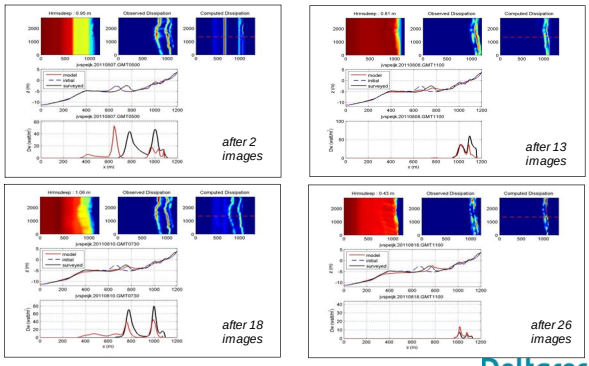
Application

Rip currents modeling and nearshore bathymetry from video data



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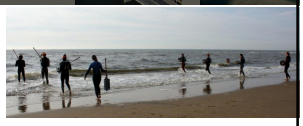
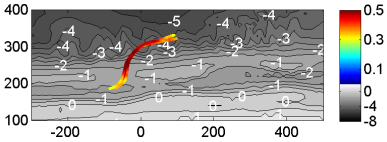
Application: Rip current forecasting

Rip current modeling and nearshore bathymetry from video data

- XBeach built and validated against drifter field measurements





Compare:

- ***Hydrodynamic results using surveyed bathymetry; and***
- ***Hydrodynamic results using Beach Wizard bathymetry***

Rip's location (spatial skill)
Rip's strength (magnitude skill)

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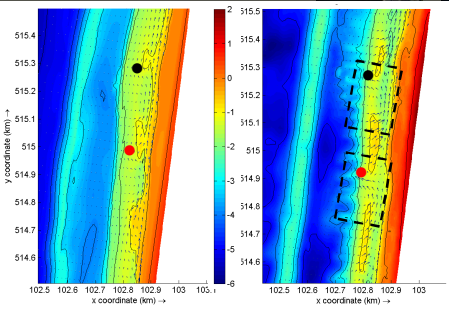
Application: Spatial skill

Rip current modeling and nearshore bathymetry from video data



Locations of max instantaneous velocity are in good agreement,
Alongshore offset : 10 m (Upper box) 70 m (Lower box)

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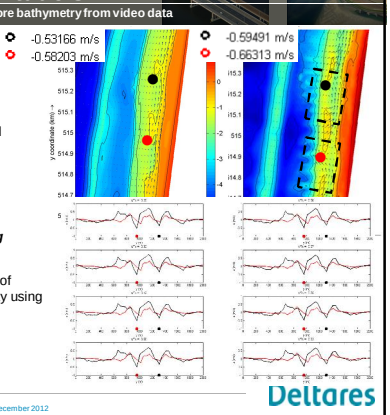
Application: Magnitude skill

Rip currents modeling and nearshore bathymetry from video data



- Difference of instantaneous maximum offshore velocity:
  - ***0.06 m/s (box 1)*** and
  - ***0.08 m/s (box 2)***
- On average, ***underestimating*** offshore velocities

Alongshore transect of offshore-ward velocity using
— Surveyed and
— Beach Wizard
Bathymetry.

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Conclusions and Further Improvements

Conclusions

1. Updated bathymetry (Beach Wizard) converges to 'true bathymetry'
2. Surveyed rip channels reproduced by the model as ridges and runnels
3. Location of predicted rip currents using Beach Wizard bathymetry and surveyed bathymetry in good agreement
4. Rip velocity (time averaged) is underestimated using Beach Wizard bathymetry while instantaneous offshore velocities are replicated well

→ Promising quality of Beach Wizard results for rip current forecasting

Further Improvements

1. *Improving bathymetry update skill by adding more sources to be used in the assimilation (e.g intertidal bathymetry and wave celerity from video data → work in progress)*

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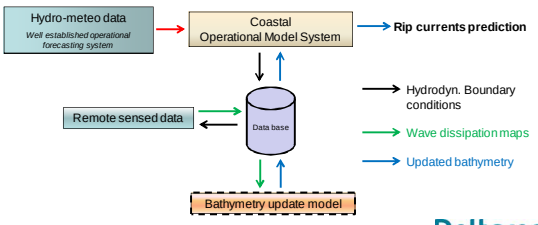
Predictive Rip Current Model

Approach

- The tools are there
  - > Model system → Deltares' Coastal Operational Model System
  - > Remote sensed video data → Argus Video System
  - > Bathymetry update using data assimilation → ***Beach Wizard***



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Nearshore bathymetry from video data

Beach Wizard **concept (van Dongeren et.al 2008)**

Formulation

$$h(t+\Delta t) = h(t) + \alpha\left(h_{obs} - h(t)\right)$$

$$h(t+\Delta t) = h(t) + \alpha \frac{1}{\frac{df}{dh}}\left(f_{obs} - f(t)\right)$$

$$h(t+\Delta t) = h(t) - \alpha \sum_{i=1}^{S} \frac{\frac{df_i}{dh}}{\left(\frac{df_i}{dh}\right)^2 + \delta_i^2}\left(f_i - f_{i,obs}\right)$$

- Weighting factor
- No direct observation of depth, but intensity as function of depth
- Uncertainty of prior and observation are needed
- Use multiple sources/intensity is possible
- Confidence interval of updated bed

$$\alpha = \left(\frac{\sigma^2(t)}{\frac{T_s}{dt}\sigma_{obs}^2 + \sigma^2(t)}\right) \qquad \sigma^2(t+\Delta t) = \alpha \frac{T_s}{dt}\sigma_{obs}^2 \qquad \sigma_{obs,i}^2 = \frac{\varepsilon_i^2 + \left(f_i - f_{i,obs}\right)^2}{\left(\frac{df_i}{dh}\right)^2} \qquad \sigma_{obs}^2 = \sqrt{\frac{1}{\sum_i \left(\frac{1}{\sigma_{i,obs}^2}\right)}}$$

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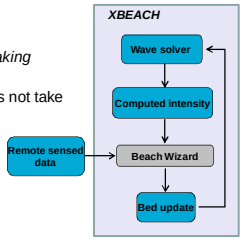
Nearshore bathymetry from video data

Beach Wizard implementation

- As a module in XBeach model system
- Run in stationary mode, using *Baldock breaking model*
- Sediment transport-based morphology does not take into account
- Simulation length per image : 1800 sec
- Time interval of bed update : 20 sec



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Nearshore bathymetry from video data

Beach Wizard **concept (van Dongeren et.al 2008)**

Beach Wizard

- Updating of bathymetry through assimilation of video-observed and model-predicted patterns of water depth-wave related phenomena
- Depth update based on difference between computed model intensity and observed intensity
- Computed intensity from numerical model (XBeach)
- Intensity *f*, has to be in function of depth h , *f* = F(h)
- For the current application, wave dissipation is used as intensity
- *Non sediment transport-based morphology*

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