Assessment of Approaches for Converting Acoustic Echo Intensity into Suspended Sediment Concentration

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Contents
- Introduction
- Methods
- Field measurements
- Results
- Outlook

Motivation
- Measurement of sediment transport is essential for:
  - coastal dynamic studies
  - maintenance of navigation channel
  - dredging monitoring
  - water quality assessments
  - set-up, calibration and validation of numerical model
  - etc.

Measuring sediment transport
- Techniques for sediment transport measurement
  - direct
  - indirect
- Direct measurement
  \[ q = u \times c \]
  \[ q \text{ in kg/m}^2\text{s} \]
  \[ q = \text{sediment transport rate, } u = \text{current velocity and} \]
  \[ c = \text{sediment concentration} \]
- Indirect measurement

Measuring sediment concentration
- Techniques for estimating sediment concentration:
  - direct sampling \(\rightarrow\) low resolution, laborious
  - optical sampling \(\rightarrow\) flow intrusive
  - acoustical profiling \(\rightarrow\) complicated

ADCP
- Stands for Acoustic Doppler Current Profiler
- Employs Doppler effect:
**Similar devices**

ADCP (RDI) 4 transducers  
Aquadopp (Nortek AS) 3 transducers  
ADV (SonTek/YSI) 3 transducers  
ADP (SonTek) 3 transducers

**ADCP data**

**ADCP backscatter**
- ADCP backscatter (=reflected acoustic echo intensity) gives qualitative measure of sediment concentration in the water column

\[
I_t \propto c
\]

- Thorne et al. (1991), Holdaway et al. (1999)

\[
c = KV_{\text{rms}} e^{-\alpha_w V_{\text{rms}}} e^{-\alpha_r r + \zeta}
\]

\[
K = \frac{c(r_r)}{V_{\text{rms}} r_r e^{-\alpha_w V_{\text{rms}}}}
\]

\[
\bar{a} = \frac{1}{R_c} \int c(r_c) dr_c
\]

\[
\alpha_w = \text{attenuation due to water}
\]

\[
\alpha_r = \text{average attenuation}
\]

\[
R_c = r_c - r_r
\]

\[
\zeta = f(\text{sediment properties})
\]

**Devices**
- trap sampler (collection of water samples)
- 1200kHz BB ADCP (backscatter data)
- optical beam transmissometer (optical transmission data)

**Empirical approaches**
- Deines (1999), SonTek (2002)
  \[
  E_l - E_l = 10 \log (c / c_0)
  \]
- Patino & Byrne (2001), Gartner (2002)
  \[
  E_l = 10 \log (c)
  \]

- Assumptions:
  - constant rate of attenuation
  - uniform sediment sizes
**Physical characteristics**

- Tide-dominated coast (semi-diurnal type, 3m range)
- Current velocity up to 1m/s
- Water depth up to 20m
- Bed sediment between 80 to 230\(\mu m\)
- Suspended sediment between 6 to 86\(\mu m\)
- Generally uniform concentration distribution

**Measuring locations**

![Measuring locations diagram]

**Measuring methods**

- Calibration (219 data)
  - data within a factor of 2: 85%
  - average relative error: 30%
  - average absolute error: 0.06kg/m³

- Validation (474 data)
  - average relative error: 32%
  - average absolute error: 0.06kg/m³

**Measurement data**

- Optical measurement
- Acoustical measurement

**Optical calibration and validation**

- Calibration (219 data)
- Validation (474 data)

**(Independent) backscatter calibration**

- 105 data
  - average relative error: 32%
  - average absolute error: 0.06kg/m³
Validation of backscatter calibration

- 5007 data pairs
- Data within a factor of 2: 93%
- Average relative error: 31%
- Average absolute error: 0.03 kg/m³

Bin and depth-averaged comparison

- Given in kg/m³

Summaries

- Approaches for converting backscatter into sediment concentration have been discussed
- An empirical conversion approach was applied
- Field measurement data were used
- Evaluation of the performance of empirical conversion approach was presented

Conclusions

- Empirical conversion approach is applicable
- Acoustic measurement results show comparable performance with respect to those given by optical measurement
- The corresponding application is limited to physical characteristics of the study site

Further works

- Estimation of cyclic sediment balance
- Improvement of calibration curves
- Consideration of changing rate of attenuation
- Consideration of non-uniform sizes of sediment
- Application of such an approach in other domain

Thank You!