Model of diffusion-convection of $^{137}$Cs for the determination of recent sedimentation rates

Paulo A. L. Ferreira, Rubens C. L. Figueira
INTRODUCTION

• $^{137}$Cs in Oceanography: sedimentation rates estimation and age modeling of sediments, source+destiny of marine sediments.
  – Artificial radionuclide (50’s – today).
  – Alkali metal.
  – High fission yield.
  – Half-life of ± 30 years.
  – Decay with $\gamma$ emission.
OBJECTIVE

• Validate the model of diffusion-convection (MDC) of $^{137}\text{Cs}$ for the calculation of recent sedimentation rates in 13 sediment cores of two Brazilian coastal systems: Cananeia-Iguape and Santos-São Vicente systems.

• Statistical validation: comparison of MDC results with data from unsupported $^{210}\text{Pb}$ modeling.
MODEL OF DIFFUSION-CONVECTION OF $^{137}\text{Cs}$

- Evolution of $^{137}\text{Cs}$ activity in a sediment core = advective and diffusive fluxes and its natural decay.
  - Diffusion to interstitial water.
  - Convection of this water.
SEDIMENTATION MODELING WITH $^{210}$Pb

- Proportional relation between sedimentation rate and unsupported $^{210}$Pb ($^{210}$Pb$_{xs}$) = creation of sedimentation models.
  - CIC.
  - CFCS.
  - ADE.
Figure 1. Study area and sampling sites.
EXPERIMENTAL

• Activities determination: $\gamma$ spectrometry.
  – HPGe detectors (mean resolution of 1.91 keV for the 1332.35 keV $^{60}$Co peak).
  – Photopeaks: 46.52 keV ($^{210}$Pb), 609.31 keV ($^{226}$Ra), 661.67 keV ($^{137}$Cs).
  – Sample analysis for 50,000 s.
  – Quality control of the results with CRMs.
Table 1. Statistical quality control of the analysis.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>CRM</th>
<th>Certified activity (Bq kg(^{-1}))</th>
<th>Measured activity (Bq kg(^{-1}))</th>
<th>Precision (RSD) (%)</th>
<th>Accuracy (RE) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{210})Pb</td>
<td>IAEA-326</td>
<td>38.40</td>
<td>39.79 ± 1.22</td>
<td>3.07</td>
<td>3.62</td>
</tr>
<tr>
<td></td>
<td>IAEA-327</td>
<td>42.36</td>
<td>43.14 ± 1.33</td>
<td>3.08</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>IAEA-385</td>
<td>25.07</td>
<td>25.16 ± 1.23</td>
<td>4.89</td>
<td>0.36</td>
</tr>
<tr>
<td>(^{226})Ra</td>
<td>IAEA-326</td>
<td>32.45</td>
<td>30.55 ± 1.50</td>
<td>4.91</td>
<td>5.86</td>
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<tr>
<td></td>
<td>IAEA-327</td>
<td>33.95</td>
<td>32.92 ± 1.54</td>
<td>4.68</td>
<td>3.03</td>
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<tr>
<td></td>
<td>IAEA-385</td>
<td>22.59</td>
<td>20.96 ± 1.52</td>
<td>7.25</td>
<td>7.22</td>
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<tr>
<td>(^{137})Cs</td>
<td>IAEA-326</td>
<td>Not a CRM for (^{137})Cs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IAEA-327</td>
<td>19.56</td>
<td>19.34 ± 1.11</td>
<td>5.74</td>
<td>1.12</td>
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<td>IAEA-385</td>
<td>26.09</td>
<td>26.66 ± 1.03</td>
<td>3.86</td>
<td>2.18</td>
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</table>
RESULTS AND DISCUSSION

Figure 2. $^{137}\text{Cs}$ vertical profiles for the cores of Cananéia-Iguape System.
RESULTS AND DISCUSSION

Figure 3. $^{137}$Cs vertical profiles for the cores of Santos-São Vicente System.
RESULTS AND DISCUSSION

Figure 4. Spatial distribution of sedimentation rates (in cm yr\(^{-1}\)) from the MDC in the Cananeia-Iguape and Santos-São Vicente systems.
# RESULTS AND DISCUSSION

Table 2. p-values (α = 0.05) for the statistical comparison of the sedimentation rates from MDC and $^{210}$Pb$_{xs}$ models.

<table>
<thead>
<tr>
<th>Test</th>
<th>Compared models</th>
<th>Test statistics</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson-Darling</td>
<td>All</td>
<td>0.63</td>
<td>0.10</td>
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<tr>
<td>Levene</td>
<td>MDC x CIC</td>
<td>0.17</td>
<td>0.69</td>
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<tr>
<td></td>
<td>MDC x CFCS</td>
<td>0.12</td>
<td>0.74</td>
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<tr>
<td></td>
<td>MDC x ADE</td>
<td>0.03</td>
<td>0.85</td>
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<tr>
<td>ANOVA</td>
<td>MDC x CIC</td>
<td>1.41</td>
<td>0.26</td>
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<tr>
<td></td>
<td>MDC x CFCS</td>
<td>0.33</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>MDC x ADE</td>
<td>1.20</td>
<td>0.29</td>
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</table>
CONCLUSIONS

• MDC was mathematically presented and validated with a statistical comparison with $^{210}$Pb$_{xs}$ models results.

• This model showed to be proper for sedimentation rates evaluation, summarizing the main phenomena responsible for $^{137}$Cs vertical migration in sediments.


• SHUKLA, B. S. Environmental Research & Publications. 1996.
THANK YOU!!

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