Water exchange between estuarine lagoon and sea through a narrow strait: case study of two Brazilian lagoons

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Water exchange regime is determined by the lagoon morphology, fresh runoff into the lagoon, local atmosperical circulation, etc.

**How to estimate role of every factor?**
**How to see, how water exchange forms?**
**Multiple regression!**

Two extreme cases:

**Patos**
- $S$ 10 360 km$^2$
- Mean depth 5 m
- Width of the strait 1 km
- Mean discharge 2500 m$^3$/c
- No tides

**Todos os Santos**
- $S$ 1223 km$^2$
- Mean depth 9,8 m
- Width of the strait 9 km
- Mean discharge 162 m$^3$/c
- Strong tides
Month variability of river discharge and salinity in the strait

14-days variability of wind and salinity in the strait

Let's take into account its interaction
Multiple regression for Patos

\[ \text{salinity} = b_0 + b_1 u + b_2 v + b_3 q, \]
\( u, v \) - wind velocities; \( q \) - discharge

On the scale of month

<table>
<thead>
<tr>
<th>River runoff</th>
<th>South wind</th>
<th>West wind</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4.97</td>
<td>0.10</td>
<td>0.03</td>
<td>0.86</td>
</tr>
</tbody>
</table>

\( R^2 \) is high enough for coefficients to be trusted.

So, variability of salinity on the scale of month is determined by variability of river runoff.

On the scale of 2 days

<table>
<thead>
<tr>
<th>River runoff</th>
<th>South wind</th>
<th>West wind</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.36</td>
<td>0.21</td>
<td>0.03</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Why is \( R^2 \) so low?

Perhaps, there are different types of water exchange in different seasons: during strong and weak river discharge.
Thus, we can see what and how forms inflows into the Patos and outflows from it! Specifically:

- 2 regimes of water exchange found, depending on the intensity of the river runoff.

- Under the weak runoff the inflow into the lagoon is usually observed, while changes in hydrological regime are mostly defined by variability of the river runoff.

- Under the intensive runoff the lagoon waters typically outflow into the ocean, however local atmospheric circulation greatly influence on the water exchange (which is brand new result!). The wind along the Patos, blowing to its inner area, causes lowering of level in the strait. Due to this surge, rare inflows occur.
Todos os Santos

Month variability of precipitation and salinity in the strait

14-days variability of east wind and salinity in the strait

Again, let's consider their interaction! But first...
Strong tides

High amplitude tides:

- semidiurnal: 37 cm
- fortnightly: 26 cm

Monthly, semi-annual and annual tides are weak (less than 10 cm).

Therefore, synoptical variability is mostly formed by the tides.
Multiple regression for Todos-os-Santos

\[ \text{salinity} = b_0 + b_1u + b_2v + b_3p, \]
\( u, v \) - wind velocities; \( p \) - precipitation

<table>
<thead>
<tr>
<th>Precipitation</th>
<th>South wind</th>
<th>East wind</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.02</td>
<td>0.00</td>
<td>0.03</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Which gives the next understanding of water exchange mechanisms:

- Seasonal variability of salinity in the strait is determined by variability of east wind. That reveals the mechanism of water exchange: east wind causes Ekman transport of ocean waters into the Todos-os-Santos, thus, from March till July, when it weakens, inflow of the ocean waters reduces. Therefore, the border between the lagoon and the sea water masses moves into the strait towards the ocean, meanwhile Todos-os-Santos freshens.

- Seasonal precipitations also influence on hydrological regime: during freshet (March-May) river runoff into the lagoon increases, that freshens the Todos-os-Santos.