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Adjusting to current climate threats and building alternative future scenarios for the Rio de la Plata coast and estuarine front, Uruguay*

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ABSTRACT

In this paper we present a climate adjustment and scenario building experience in the coastal areas of Uruguay within the framework of GEF-Project ”Implementing pilot sites adaptation measures in coastal Uruguay”. The Project goals are to increase resilience, promote interactions between relevant institutions and stakeholders, and to incorporate climate threats in the political agenda. Assuming that many readers are more familiar with Integrated Coastal Zone Management (ICZM) than with climate adaptation a summary of concepts is presented based on both the international literature and local experience. Emphasis is put on the knowledge of coastal climate-driven threats, the implications of adaptive and risk-based management approaches to current climate, adaptation planning, and future scenarios. Then, a review of our recent publications on the subject is made in order to give a picture of the lessons learned during the Project experience. Here we focus on the Rio de la Plata's estuarine front "Adaptation Pilot Site" and the interaction between scientists and stakeholders from 2009-2013. Emphasis is put on recent climatic time-series (1997-2012) since during this period most of them reverted as compared to the Project's climate baselines (1961-2008). This short-term variability is fundamental to cope with current climate threats (adjustment) and introduces additional uncertainties to future scenarios. The continuous interaction with stakeholders and experts allows building alternative futures from the current perspective and climate models. The process itself - planning and implementing actions - creates capacity to move forward. Natural and social scientists continuously inform stakeholders, to promote adjustment, interactive adaptive management, and planning. Thinking of "futures" together with experts and stakeholders can be thought as a "what if" learning exercise and a way to develop alternative scenarios.

Keywords: Adaptation Concepts; Climate Drivers; Monitoring.

RESUMO

Enfrentando as ameaças climáticas atuais e construindo cenários futuros alternativos para a costa e frente estuarina do Rio de La Plata, Uruguai

Neste artigo apresentamos uma adaptação climática e uma construção de cenários baseados na experiência nas áreas costeiras do Uruguai, no âmbito do Projeto GEF- "Implementacao de medidas de adaptação em locais pilotos na costa do Uruguai". As metas do projeto são aumentar a resiliência, promover as interações entre instituições e as partes interessadas, no senso de incorporar as ameaças climáticas na agenda política. Partindo do princípio que muitos leitores estão mais familiarizados com a ICZM do que com a adaptação climática é apresentado um resumo de conceitos com base a literatura internacional e experiência local. A ênfase é colocada sobre o conhecimento das ameaças provocadas pelo clima do litoral, as

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implicações de adaptação e gestão baseada em risco se aproximam ao clima atual, o planejamento de adaptação, e cenários futuros. Então, nossas recentes publicações sobre o assunto são revisadas, a fim de dar uma imagem das lições aprendidas durante a experiência do Projeto. Aqui nos concentramos em na frente estuarina do Rio de la Plata "Local piloto de adaptação" e da interação entre os cientistas e os interessados entre 2009 e 2013. Ressaltamos sobre a evolução da recente série temporal climática (1997-2012), quando a maioria deles com uma tendência revertida em comparação com as linhas de base do clima do projeto (1961-2008). Esta variabilidade de curto prazo é fundamental para lidar com as ameaças climáticas atuais (de ajuste) e introduzem incertezas adicionais as típicas dos cenários futuros. A interação contínua com as partes interessadas e especialistas permite construir futuros alternativos a partir da perspectiva atual e os modelos climáticos. O processo em si - o planejamento e implementação de ações - cria capacidade para avançar. Os cientistas naturais e sociais informam continuamente as partes interessadas para apoiar o ajustamento atual, a gestão adaptativa interativa e o planejamento. Pensando em "futuros", juntamente com peritos e partes interessadas pode ser pensado como um exercício "what if" e uma maneira de desenvolver cenários alternativos de aprendizagem.

Palavras-chave: *adaptação, forçantes climáticos, monitoramento, cenários.*

1. Introduction

This paper is one of four written for the GEF project "*Implementing Pilot Adaptation Measures to Climate Change in Coastal Areas of Uruguay",* from now on "the Project" (UCC, 2011, http://www.adaptationlearning.net). The three other papers, which will be summarized in section 4 and Table 1, discuss the methodological evolution to cope with observed and current variability and to adapt to future climate change at the pilot sites "Laguna de Rocha", an estuarine coastal lagoon at the Atlantic coast (10 km to the west of La Paloma, Figure 1), and the "Estuarine Front", where fresh and seawater mix within the Rio de la Plata river estuary (Figure 2).

The development and approaches of the Project were both supported and inspired by EcoPlata Program, a successful Integrated Coastal Zone Management (ICZM) Program (Gómez-Erache *et al*., 2010; Nagy *et al*., 2014a).

According to Christie *et al*. (2005) "Integrated Coastal Zone Management" (ICZM) assumes interdependence of coastal human communities and associated resources,

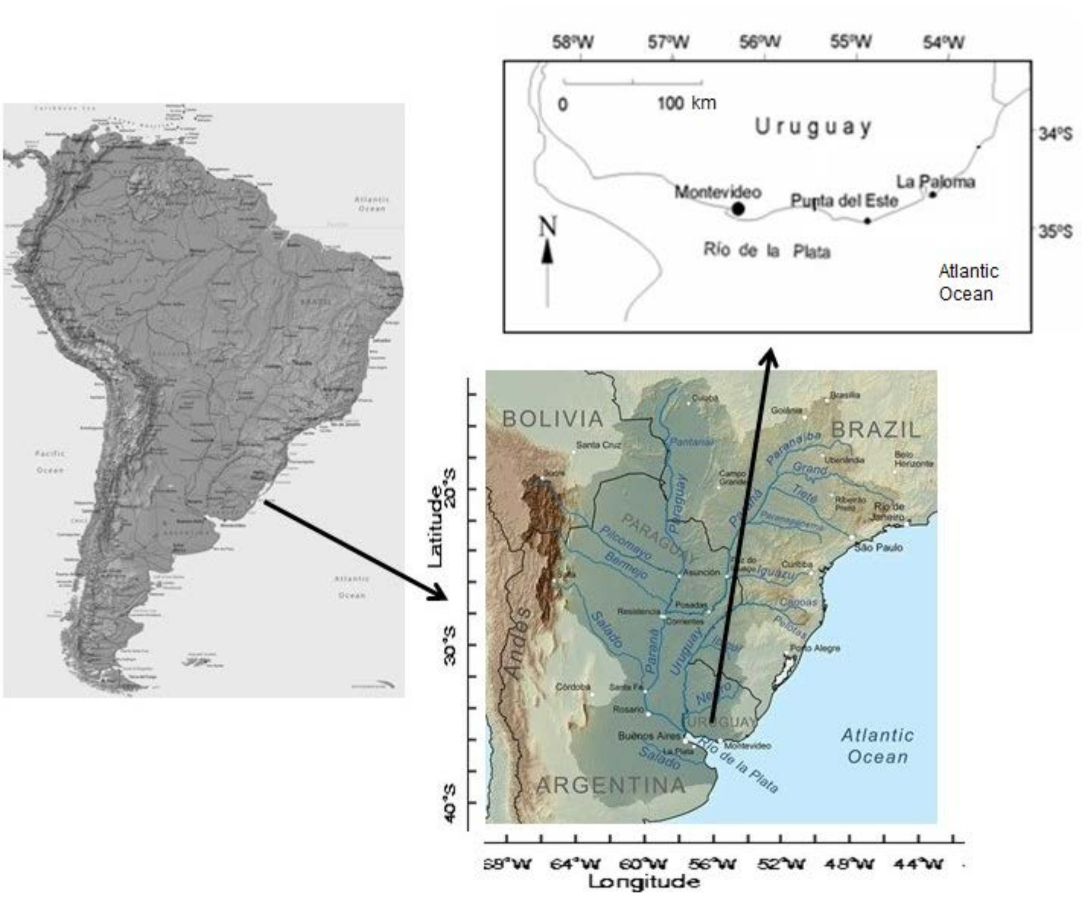

Figure 1 - Rio de la Plata basin and river estuary, Southeastern South America. Source: Nagy *et al*. (2014a).
Figura 1 - Bacia e estuario de Rio de la Plata, Sudeste da América do Sul. Fonte: Nagy et al. (2014a).

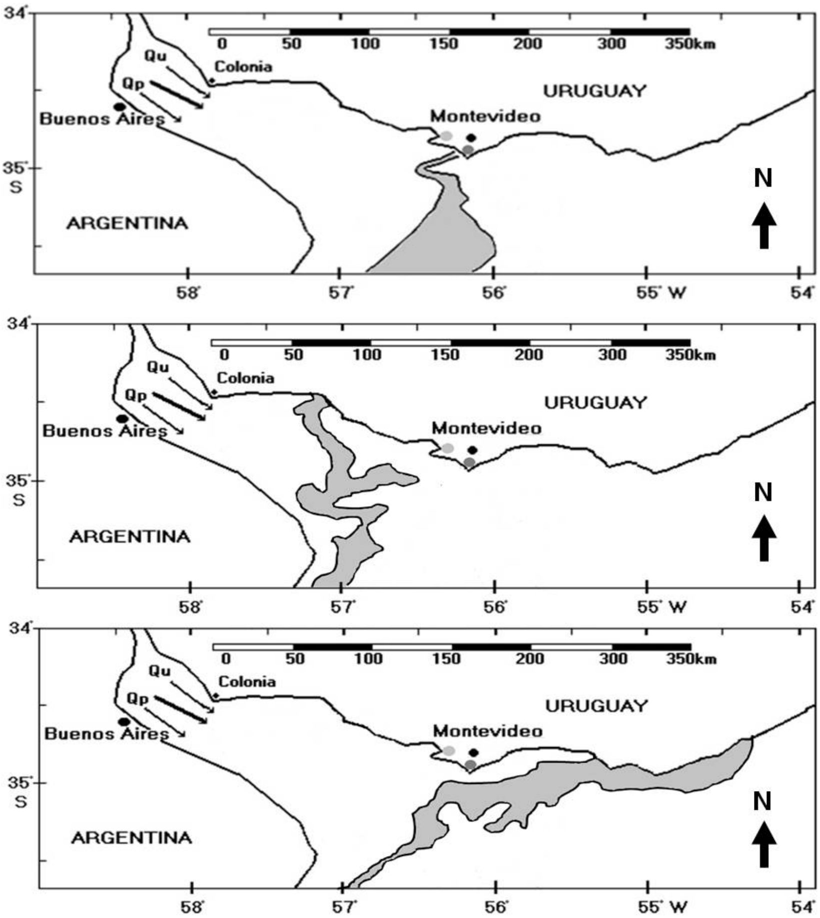

Figure 2 - Schematic estuarine frontal system-EFS (shadowed area). The gray color represents the area of frontal mixing of fresh- and sea-water with typical salinities about 1-12. The three shown locations and dates represent: i) average flow (upper, 11/27/03,) close to Montevideo, ii) up-river (middle, 02/09/09) due to an extreme La Niña-related low flow, and seaward (below 09/20/09) due to an extreme El Niño-related high flow. Modified from Lappo *et al*., 2005 and Nagy *et al*. (2008a, 2013, 2014a).

Figura 2 - Esquema do sistema frontal estuarino EFS (área sombreada). A cor cinza representa a área de mistura frontal de água doce e água do mar com salinidades típicas cerca de 1-12. Os três locais e datas indicados representam: i) vazão média (superior, 11/27/03), próximo a Montevidéu, ii) rio superior (médio, 02/09/09) devido a um baixo fluxo relacionado com o evento La Niña extremo, e ao largo (abaixo de 09/20/09), devido a um alto fluxo extremo relacionado com o evento El Niño. Modificado de Lappo et al., 2005 and Nagy et al. (2008a, 2013, 2014a).

calls for user conflict resolution and the reduction of cumulative impacts, and considers local participation as a critical management component". According to Conde *et al*., (2012) "In an ICZM context, the contributions from academic studies are critical for making management decisions based on the best scientific information available".

In agreement with these statements, the Project understood ICZM approach was a framework in order to resolve conflicts of climatic origin with stakeholders' participation. The EcoPlata Program (http://www.ecoplata.org) has focused since 1994 on the strengthening of institutional capacity, the scientific community, managers and public in general, in all issues relative to ICZM strategy, including climate indicators and vulnerability assessments. Both the Project and EcoPlata Program aim to develop strategies to effectively manage future climate change impacts by promoting a participatory and adaptable management model, developed over many years by EcoPlata. This model is based on technical and scientific research and capacity building of institutions and local stakeholders, so that knowledge can be integrated into the design and application of policies and collective action (Gómez-Erache *et al*., 2010; Nagy *et al*. 2014a). Analysis of the combined experience of both initiatives has revealed some significant lessons learned. Firstly, coastal adaptation efforts need to build on, and support, existing frameworks for ICZM efforts to strengthen coastal zone management. Secondly, the enhanced coordination in assessment of extreme event-related impacts was the main driver to increased awareness. Thirdly, providing a strong scientific basis and understanding around coastal processes and climate change has proved to be very effective in moving the adaptation agenda forward in country. Usually ICZM in Uruguay deals with current issues, including climatic variability and extremes, and vulnerability (Nagy *et al.* 2014a).

The goals of this article are to:

- Revisit and synthesize recent literature on climate change and variability adaptation experiences and lessons in coastal Uruguay.
- Update current climatic data useful to coastal management and climate adaptation, over the past few years (1997-2012).
- Present participatory alternative climate scenarios for 2030-50.
- Focus on the Rio de la Plata Estuarine Front pilot site.

2. The Uruguayan Coast and the Rio de la Plata Estuary: a Climate Perspective

The Republic of Uruguay (177,000 km^2) is located in the La Plata River Basin (which spreads over a 3,1 million km^2, Figure 1). The Uruguayan coast is 670 kilometers in length with 450 km lying along the Rio de la Plata estuary (38,000 km^2, average depth <10 m) and the remaining 220 km along the Atlantic Ocean. The complex geophysical environment of the Uruguayan coast within the Rio de la Plata is under stress from existing pressures such as changing hydro-climatic and wind regimes, sea-level rise, extreme events, growing population and associated increases in development over the last few decades (Nagy *et al.*, 2008a, 2013a, 2014a).

The rivers Parana and Uruguay are major tributaries of the Rio de la Plata. Total yearly river inflow (Q_{RP}) varies between 22,000 and 28,000 m^3/s during normal years and <20,000 m^3/s and >30,000 m^3/s during dry and wet years, often associated with La Niña and El Niño events, respectively (Nagy *et al.* 2008a). The flows of both rivers mix with the Atlantic Ocean within the Rio de la Plata microtidal river estuary system. The mixing zone or estuarine frontal system (EFS) may be defined by discontinuities of turbidity where fresh turbid water and marine green water prevail up and down-river the estuarine frontal system respectively. The cyclic variability of river flows displaces the EFS up-river with low flow and down-river with high flow (Figure 2) and changes salinity and turbidity on seasonal and interannual time-scales, which impact its environment and resources. Most observed interannual variability over the last two decades is ENSO-related, e.g., El Niño events of 1997-98, 2002-03, 2009-10 and La Niña events of 1999-00, 2008-09, 2011-12. These flows and their seasonal and interannual variability have significantly increased over the last five decades, especially from 1971-1997 (Garcia & Vargas, 1994; Nagy *et al*., 2008a; Nagy *et al*., 2013a).

Climatic time-series of temperature, rainfall, river flows, and sea-level have shown positive trends from 1961-2008 (Bidegain *et al*., 2005, 2009), whereas wind regime has slightly changed, with an increase in south-eastern winds. All of these changes are expected to continue until 2030-50 (Bidegain *et al*., 2011a,b). The increase in the occurrence of extreme events such as wind storm surges over the last few years is the greatest coastal concern if this trend is to be continued (Verocai *et al*., 2013). Only the increase in storm-surges is already directly affecting the coast, whereas both the observed moderate sea-level rise (SLR: 11-12 cm) and the increase in freshwater inflow to the Rio de la Plata river estuary trigger the effects of wind-storms (Bidegain *et al*., 2005, 2009; Nagy *et al*., 2007, 2013b; Verocai *et al*., 2013; Gutiérrez *et al*., 2013).

3. Clarifying concepts on climate adaptation

Assuming that many readers are more familiar with Integrated Coastal Zone Management (ICZM) than with Climate Change impacts, adaptation and vulnerability (IAV) and because some terms have different meanings, we present the definitions and concepts used in this paper based on recent literature and our experience.

According to Weber (2006), evidence-based perceptions of long-term risk show that global warming does not scare us yet. Here we understand "*Climate threat*" as any "climate-driven, continuous (climate change) or discrete (extreme weather or climate-related events) stressor on the environment and humans", and the ambient stressors, risk domain, and impacting processes associated with (Adapted from Reser & Swim, 2011).

The perceptions of climate threats are usually incorporated into participatory decision-making and action processes (Tompkins, 2005; Few *et al.*, 2007; Eisenack *et al*., 2007; Nagy *et al*., 2014b). Public participation encompasses a range of procedures and methods designed to consult, involve, and inform the public to allow those that would be potentially affected by a decision or policy to have input into the process. The latter are also known as Stakeholders (IFC, 2007). The IPCC (2007) defined Climate Vulnerability, Adaptation and Scenarios as follows:

- Vulnerability: "the degree to which a human or natural system is susceptible to, or unable to cope with, adverse effects of climate change".
- Adaptation: "the adjustment in natural or human systems in response to actual or expected climatic

stimuli or their effects, which moderates harm or exploits beneficial opportunities" respectively.

- Scenarios: "plausible futures that allow you to envision and evaluate the outcomes of potential decisions in the context of different sets of background conditions".

Several authors have argued that there are societal limits to climate adaptation (Adger *et al*., 2009), or that it will likely fail (Dessai & Van der Sluijs, 2007), whereas Johnston *et al*. (2013) stated' Failure of climate change adaptation and rising greenhouse gas emissions as among those global risks considered to be the most likely to materialize within a decade'.

According to Dessai & Van der Sluijs (2007) some relevant concepts of *uncertainty and climate change adaptation* are as follows:

- "Statistical uncertainty concerns the uncertainties which can adequately be expressed in statistical terms, e.g., as a range with associated probability".
- "The top-down-prediction-oriented-approaches are strong in statistical uncertainty and the resilience and robustness type of bottom-up approaches are strong in coping with recognized ignorance and surprises".
- Scenario uncertainty concerns uncertainties which cannot be adequately depicted in terms of probabilities, but which can only be specified in terms of (a range of) "possible outcomes" Thus, *s*cenario uncertainties are often constructed in terms of "what-if" statements.

To simplify the sometimes confusing concepts of vulnerability and risk, Nagy *et al*. (2013a, 2014b) used an operational understanding for both of them as follows:

- "Impact-oriented vulnerability", where threats and vulnerability are perceived as "any possible harm or loss and potential impacts" respectively.
- "Climatic risk" could be "any possible threat from observed and possible change, variability, and extremes, which probability distribution is not always well characterized".

Climate change may mean more frequent extreme events, or more severe extreme events, in the future. Adaptation planning for these events will strongly rely on lessons learnt in past events (Kiem *et al*., 2010). A lack of adaptation to current climate variability and observed change is a failure to keep pace with development called by Burton (2004) "adaptation deficit". This concept captures the notion that countries are underprepared for current climate conditions, much less for future climate change. The shortfall is not the result of low levels of development but of less than optimal allocations of limited resources (World Bank, 2010).

Scenarios in the area of climate and global change assessment are dominated by exploratory, top-down scenarios in forecasting mode. However, the research community is making a serious effort to develop *participatory scenarios* that cross the boundaries between knowledge and action and are salient, credible and legitimate (after Cash *et al*., 2003, in Jones 2010a). Scenarios do not tell us what will happen but they can be used as a tool to identify future actions. Scenarios are used widely in vulnerability and risk assessment exercises to inform impact models from which scientists, managers and/or resource-users identify adaptation strategies to minimize risk. Rarely do these processes go on to appraise, evaluate, or implement the adaptation strategies identified (Wilby & Dessai, 2010).

Scenario planning allows managers to envision a range of possible futures. These futures may be near-term and simple (what if?), or they may be long-term and complex, addressing the interactions of highly uncertain drivers. All scenarios should take into account relatively well-known trends. Scenario planning is not merely a prediction, but is a systematic way of bracketing uncertainty. Scenario planning or "participatory scenario analysis" supports the interaction of diverse participants (*e.g*., community stakeholders, political decision-makers, resource managers, scientists) to develop a shared understanding of risks, trade-offs, and possible management actions" (Cobb & Thompson, 2012; Moore *et al*., 2013). The use of "what if" or "what future do you envision" seems useful to communicate uncertainty and risks to the stakeholders (Nagy *et al*., 2014b).

A closer scrutiny of the risks reveals that many coastal adaptation actions appropriate for long-term planning are identical to those employed to manage or mitigate severe and more immediate impacts of other coastal hazards (Bender 2011; Dholakia-Lehenbauer & Elliott, 2012). Climate change and sea-level rise will usually be on the list of justifications to present adaptation options but are often less compelling threats than other appropriately presented coastal hazards (Rogers & Tanski, 2012).

Risk-management encompasses the implementation of strategies for reducing vulnerabilities to risk, increasing resiliency to problematic conditions, and positioning resources to exploit opportunities (Mahmoud *et al*., 2009). In this regard Preston *et al.,* (2013) said "Climate adaptation has emerged as a mainstream risk-management strategy for assisting in maintaining social-ecological systems within the boundaries of a safe operating sp*ace*". Often, there are not accepted metrics to assessing threats and risks. Scientists provide historical records of extremes, recurrences, projections, and future scenarios to stakeholders who rank impacts and threats based on this information, their perception, and priorities. Certainly, a great degree of uncertainty remains and that is why climate adaptation is basically a risk-management approach. In other words, what happens if the assumptions, scenarios and/or actions are wrong? (Jones, 2010b). "Adaptive co-management can be thought as a making-decision and learning by-doing process in which stakeholders operate under uncertainty" (Tompkins, 2005). According to Butler & Coughlan (2011) this requires continued reevaluation of locally and temporally relevant management strategies so that they evolve along with the climate. They suggest to adapting the concept of variability as a proxy of change.

4. Revisiting recent contributions and methodological approaches

This paper explores previous experiences of the Project during the period 2008-13 aiming to link climate and coastal science, effective communication with stake-holders, and management. For doing so, a brief synthesis of the main goals, methodological approaches, results and learned lessons are presented based on recent literature.

4.1. Recent Contributions

Three recent peer reviewed contributions of the Project's series "Approaches to Implementing Coastal Adaptation in Uruguay" (www.adaptationlearning.net) are revisited. These articles, summarized in Table 1, are:

1. A risk-based and participatory approach to assessing climate vulnerability in coastal Uruguay (Nagy *et al*., 2014a).
2. Stakeholders' climate perception and adaptation in coastal Uruguay (Nagy *et al*., 2014b).
3. Integrating climate science, monitoring, and management in the Rio de la Plata estuarine front, Uruguay (Nagy *et al.*, 2014c).

4.2. Methodological Approaches

The methodology followed in this article to plan and implement measures in coastal pilot adaptation sites builds upon the three above mentioned ones (Table 1). All of them share:

- The classical IPCC-type science-driven, prescriptive top-down General Circulation Models (GCMs) in forecasting mode.
- Expert judgment matrices included to support decision-making.
- A diagnostic bottom-up participatory approach based on the UNDP Vulnerability Reduction Assessment Approach-VRA (Droesch *et al.,* 2010) was followed to inquire stakeholders' perceptions about climatic threats and adaptations constraints and options.
- A participatory process, e.g., several meetings, semi-structured and in depth interviews, and workshops with identified stakeholders, scientists, practitioners were held to select, prioritize, and define adaptation options to be planned or implemented.
- Adaptive and risk-based management type approaches were discussed with stakeholders.

This article shares with the third one (Nagy *et al*., 2014c) the use of a system dynamics (SD) approach. System dynamics is an approach to understanding the behavior of complex systems over time. It deals with internal feedback loops and time delays that affect the behavior of the entire system (Sterman, 2001). An original SD stock and flow model diagram is presented. Stock and flow model helps in studying and analyzing the system in a quantitative way. A stock is the term for any entity that accumulates or depletes over time. A flow is the rate of change or accumulation of the stock (Meadows, 2008).

Finally, an original participatory scenario planning is explored in this article. According to the U.S. National Climate Assessment (NCA, 2013) the primary purpose of this approach in climate assessment has been the application of information about the range of potential future conditions to identify robust options for development, resource and management. Some benefits of a participatory approach are communication and understanding of uncertainties, consideration of local knowledge and perspectives, co-creation of scenarios that stretch thinking of scientists and decision makers about adaptation options, and development of motivation to act on the information gained. In contrast to prognoses, the scenario analysis is not using extrapolation of the past. It does not rely on historical data and does not expect past observations to be still valid in the future.

The approach followed in this article is the development of alternative contrasted scenarios or "futures" with two opposed climatic trends which must be plausible and logic (Cobb & Thompson, 2012; Moore *et al*., 2013).

5. Updating current climatic scenario and impacts for adjustment

According to Moss et al., (2010) because of the extensive uncertainties that exist in the future drivers of and responses to climate change, future scenarios are necessary to explore the potential consequences of different management response options.

5.1. Climate scenarios

The Project developed time-series for the period 1961-2008 (current baselines), e.g. sea-level rise (Fiure 3) and future GCM-based climate scenarios (HADCM4 and ECHAM5) downscaled with Hadley PRECIS tool to regional scales of 50 x 50km (Bidegain *et al.*, 2009; Nagy *et al.*, 2014a), as well as the high resolution (60 x 60 km)MRI-JMA CGCM2.3 (Bidegain *et al.*, 2011a).

In order to plan, select and prioritize the adaptation measures to be implemented this knowledge was communicated and discussed with the stakeholders. It was outlined that several variables such as the total river inflow to the Rio de la Plata (Q_{RP}) and sea-level were below the long-term trend since ca. 2004. River flow fluctuations, wind regime, and SLR are sensitive to ENSO variability (Gutierrez *et al.*, 2013; Nagy *et al.*, 2013a,b). This influence on SLR is explained by the local effect of a close mouth of a great river (Nicholls *et al.*, influence sea-level all along the Uruguayan coast (Bidegain *et al.*, 2009; Nagy *et al.*, 2014b). This influence reaches +/- (up/down) 5-20 cm/year (Nagy *et al.*, 2005; Bidegain *et al.*, 2009),

Table 1 - Summary of aims and methodological approaches, results, and lessons of the Project's recent peer reviewed contributions.

Tabela 1 *- Resumo dos objectivos e abordagens metodológicas, resultados e lições de contribuições recentes do Projeto.*

Article	Aims and Methodological Approach	Results	Learned lessons
1 Nagy *et al.*, 2014a	**Aim**: To Increase resilience and capacity to link ICZM and participatory climate adaptation at two Pilot Sites (Laguna de Rocha - a coastal lagoon - and the Frontal Zone of Rio de la Plata river estuary). **Approach**: In order to assess the potential risks of climate change on the pilot sites, four "cascading" supporting streams of activity were undertaken, namely: 1. Vulnerability mapping to consider key system drivers. 2. Baseline Vulnerability Reduction Assessment (VRA). 3. Development of a customized risk management conceptual model (MESA). 4. Multi-criteria approaches for selecting adaptation options.	The Uruguayan coast was identified as one of the most exposed in Latin America to sea-level rise and wind-induced flooding.	Adaptation efforts need to build on existing frameworks for ICZM. Providing a scientific understanding of coastal processes and climate change has proved to be very effective in moving the adaptation agenda forward in country.
2 Nagy *et al.*, 2014b	**Aim**: To review stakeholders' involvement in adaptation planning focused on the Laguna de Rocha (coastal lagoon) site. **Approach**: A combination of top-down climate analysis and modelling, and expert judgment with a participatory process including consultations, workshops, and a VRA intended to inquire stakeholders' perception of coastal climate threats and adaptation was followed to prioritize actions.	The project incorporated stakeholder analysis, climate scenarios, and the necessary trade-offs in order to manage climate change. This process empowered stakeholders.	Stakeholders understand future scenarios with difficulty. Thus, vulnerability was assessed with stakeholders following an impact-oriented perspective. The success of integrating scientists and stakeholders into the management policy is a learning-by-doing lesson. Stakeholders prefer no-regret adaptation measures which facilitate conflict resolution.
3 Nagy *et al.*, 2014c	**Aim**: To focus on institutional arrangement for managing climate variability risks within the Rio de la Plata Estuarine Front Pilot site. **Approach**: The use of a system dynamics stock and flow diagram was explored as a tool to analyze the complexity of multi-causal problems and the implementation of a monitoring-modelling-early warning system to support the implementation and timing of management options.	Periodic hydro-climatic fluctuations, often in coincidence with ENSO induced variability, allows the development of an early warning system to support management.	The institutional agreements and the consultation process imply stakeholders' ownership and facilitate the implementation. Monitoring of ENSO related variables allows forecasting the future behavior of the estuarine front displacement and salinity close to Montevideo.

which is far greater than the observed 0.11 cm/year SLR from 1902-2002 (+ 11cm), reaching 0.3 cm/year from 1971-2003 (Magrin *et al.*, 2007; Bidegain *et al.*, 2005, 2009), or only 0,1 cm/year from 1961-2012 (Verocai *et al.*, 2013).

These cycles and short-term trends are discussed during participatory adaptation meetings because stakeholders expressed to be more concerned by recent trends (5 to 20 years), and extreme events, than by long-term series and GCMs' outputs (Nagy *et al.* 2014b).

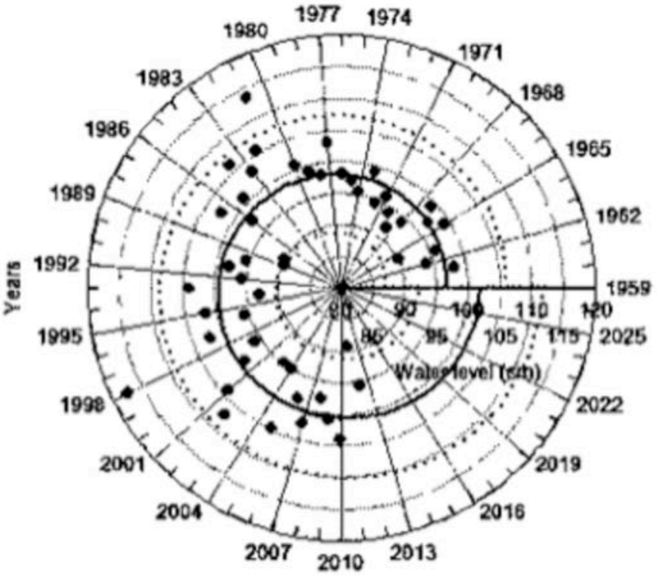

Figure 3 - Sea-level rise in Montevideo (1961-2012). The circular mode shows the years (points), the increasing trend (line) from 96 to 101 cm, and 95% confidence interval (dotted line). The regressive projected value for 2025 is 102 cm (range: 92-112 cm).

Figura 3 - Elevação do nível do mar, em Montevidéu (1961-2012). O modo circular mostra os anos (pontos), a tendência crescente (linha) 96-101 cm, e intervalo de confiança de 95% (linha pontilhada). O valor projetado regressivo para 2025 é 102 cm (intervalo: 92-112 cm).

The update of the series up to 2012 show that all positive climatic trends during the period 1961-2008 reverted to negative ones from 1997-2012 - except for temperature - (Nagy *et al.*, 2013b), *e.g.*, the ENSO Equatorial Pacific Index Sea Surface Temperature (SST 3.4), the regional river inflow, and the local SLR (Figure 4). Even if communication and participatory processes have increased stakeholders' understanding of the need of analysing 30 years and plus climatic data, they are concerned by short-term trends and cycles. In this regard, Nagy *et al.* (2014b) argue that long-term robust trends over the last few decades created a "perceived continuity of changing" among stakeholders that may overcome the uncertainty about future climate change.

A common pattern shown in figure 4 is the decrease since 2003-04. Are really these trends that robust or just a cycle? Kosaka & Shang-Ping (2013) have shown that the recent observed decrease in the pace of global warming (from late 90s) - when compared to that of atmospheric carbon - or the "g*lobal-warming hiatus",* might be tied to a decadal variability (Pacific Decadal Variability - PDO) of Equatorial Pacific surface cooling *or "*La Niña-like decadal cooling*"*. A question that remains to be answered is if the recent short-term climatic trends observed in coastal Uruguay could be linked with PDO.

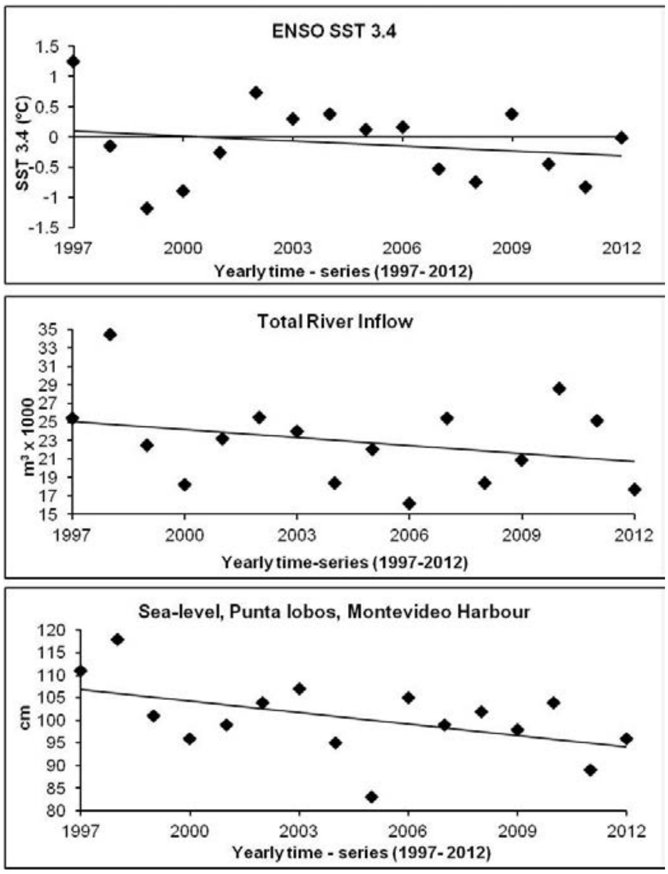

Figure 4 - Yearly means time-series from 1997-2012 for ENSO SST 3.4 index (above), river inflow to the Rio de la Plata (middle), and seal-level rise in Montevideo (below). Accordingly to Nagy *et al.*, (2013b).

Figura 4 - Serie temporal anual do indice ENSO SST 3,4 do período 1997-2012 (acima), fluxo de entrada no Rio de la Plata (meio) e elevação do nível do mar em Montevidéu (abaixo). Segundo Nagy et al, (2013b).

5.2. Climate threats, impacts and stakeholders' adjustment

The overall observed impacts on coastal communities and sectors associated with climate threats and SLR remains low to moderate, *e.g.*, low physical capital losses and low human risk. However, locally, the experience of impacts may be sometimes greater (Nagy *et al.* 2007; 2014b; Gomez-Erache *et al.*, 2013). The main climate threats and impacts, and some stakeholders' responses are synthesized (Table 2).

The participation of local citizens and other stakeholders in the adjustment to climate change processes in Uruguay usually occurs within the national and local level institutional and legal framework which promotes public consultation.

These participatory processes empower stakeholders without a perceived loss of power from the institutions (Nagy *et al.*, 2014b). Autonomous community-level responses are not frequent, with the exception of artisanal fishermen who migrate as a response to climate variability within the estuarine front (Nagy *et al.*, 2008b; 2014c).

One of the goals of the Project is to link science with management and to communicate it to stakeholders in an effective way. In order to do so, a system dynamics approach was used. A stock and flow diagram of the climatic and oceanographic variables (Figure 5) was developed to explain the behaviour of the Rio de la Plata estuarine front (Nagy *et al.*, 2013b,c). This approach simplifies the complexity by focusing on the key variables.

In our example, there are three key variables: Global Warming, El Niño (represented by SST 3.4), and Pacific Decadal Oscillation (PDO). There are two stocks: Salinity and Turbidity, associated with freshwater and suspended matter inputs to the system respectively. There are three flows: River Inflow (m^3/s), basin and local rainfall (mm), and frontal (EFS) displacement (km) all of which are scaled to monthly time-scale. Time delays (months) represent the typical cause-effect lag of time, e.g., an increase in SST 3.4 (El Niño) is followed by an increase in river inflow 3-6 months after.

The diagram shows both the plausible influence of PDO and the well-known ENSO-related variability on climatic drivers and relationships relevant to explain the observed trends and the possible near future. The diagram is centered on the displacement of the estuarine front (see figure 2) because it is - together with sea-level - associated with the main regional climate drivers, river inflow and wind. Running "what if" simulations to test certain auxiliary variables or flows on such a model can greatly aid in understanding how the system changes over time.

This diagram will be useful not only to make simulations but as a tool to illustrate complexity and for developing creative scenarios based on how the system changes with climate drivers or policy measures. Unfortunately, there is not much to be done to control and manage the drivers of change and variability shown in the diagram (due to the huge dimensions and geopolitical complexity of the basin), but enhancing modeling, monitoring, communication to users, and rapid response.

Table 2 - Participatory climate scenario for adaptation planning. Expected changes are represented by symbols:not significant (=), increase (+), and decrease (-). Based on Escobar et al. (2004); Bidegain et al. (2005; 2011a, b; 2012); Camilloni & Bidegain (2005); Nagy et al. (2008 b, 2014a); Alves & Marengo (2010).

Tabela 2 - Cenário climático participativo para o planejamento da adaptação. As mudanças esperadas são representadas por símbolos: não significativo (=), aumento (+) e diminuição (-). Baseado em Escobar et al. (2004); Bidegain et al., (2005; 2011a, b; 2012); Camilloni & Bidegain (2005); Nagy et al. (2008 b, 2014a); Alves & Marengo (2010).

Climate threats, magnitude, effects and impacts		**Stakeholders' response**	**Sources**
Threat and Magnitude	**Effect and Impact**		Nagy et al. 2014 a,b,c. for all of the threats
Sea-level rise: Weak (≤ 12 cm)	Weak to moderate Beach and Wetland loss	Diagnostic reports	Bidegain *et al.* (2005, 2009); Gómez-Erache *et al.* (2013); Nagy *et al.* (2014b); this article
Increase in River inflow: Strong (> 25% since 1971) and variability	Moderate to Strong Estuarine front sea-ward displacement	Fishermen migration	García & Vargas (1994); Nagy *et al.* (2008b, 2013a,b); this article
ENSO-related Wind regime variability: Moderate to Strong	Weak to Moderate Beach erosion (up to 32% erosive coast)	Beach, dune, and lagoon-bar management and "soft" protection	Nagy *et al.* (2007, 2008b); Bidegain *et al.* (2009, 2011b); SNRCC (2010); Gutiérrez *et al.* (2013); Gómez-Erache *et al.* (2013); Conde *et al.* (2013); Verocai *et al.* (2013)
Increase in storm-surges	Overall coastal erosion; increase of physical, economic and natural capital at risk.	Diagnostic reports and emergency response plans	
Increase in local rainfall: (≥ 23 %) and regime change	Moderate to strong Beach and Cliffs erosion; (episodic) decrease in beach microbial quality	Beach and dune soft protection. Municipal beach monitoring and bath restrictions	Bidegain *et al.* (2005, 2009); Nagy *et al.* (2014c)

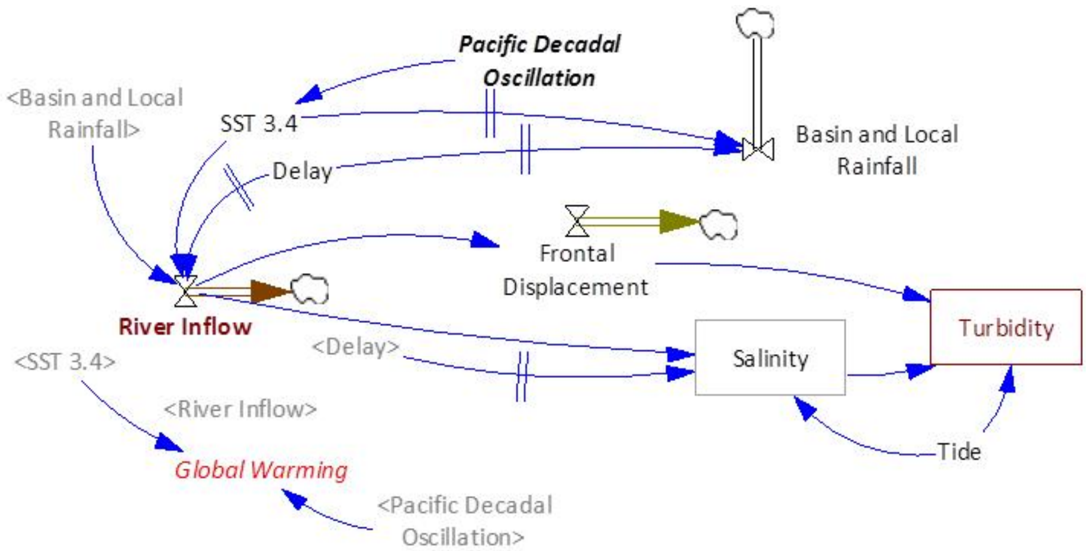

Figure 5 - Stock and flow diagram (VENSIM System Dynamics software) of the Rio de la Plata Estuarine Frontal System. Boxes: stocks (accumulations), e.g., freshwater (salinity) and suspended matter (turbidity). Narrow arrows: direct relationship between auxiliary variables, e.g., El Niño (SST 3,4) increases rainfall. Delay is a time lag of a cause-effect relationship. Wide arrows: flows, e.g. river inflow, frontal displacement, and rainfall. Accordingly to Nagy *et al.* (2013b,c).

Figura 5 - Diagrama de estoque e fluxo (software System Dynamics VENSIM) do sistema frontal estuarino do Rio de la Plata. Caixas: estoques (acumulações), por exemplo água doce (salinidade) e material em suspensão (turbidez). Setas estreitas: relação direta entre variáveis auxiliares, por exemplo, El Niño (SST 3,4) aumenta a pluviosidade. O atraso (Delay) é um intervalo de tempo de uma relação causa-efeito. Setas largas: fluxos, por exemplo, fluxo do rio, o deslocamento frontal, e precipitação. Segundo Nagy et al. (2013b, c).

From a management perspective, any soon change in the pace and trends of climate drivers will increase stakeholders' trust on scholars, and probably on the new generation of future scenarios. In this regard, the role of social scientists and communicators is central, together and in narrow coordination with natural scientists, to increase public awareness.

Even if some institutional stakeholders and elected officials do not believe in climate change or prefer to ignore it because of the priority of economic development, they cannot completely ignore people's concerns and must pay careful attention to climate trends and threats. The project is continuously updating data and generating plausible future scenarios based on models and projections within an adaptive- and risk-based co-management approach.

6. A simple scenario for adaptation planning

The Project followed a mixed approach to construct participatory scenarios based on the prescriptive GCM models future outputs, e.g., 2030 to 2050, the projection of robust trends, e.g., 1961-2008, and discussions with experts and stakeholders. The participatory phases involved in depth interviews, impact-ranking with analysis of obstacles, opportunities, time-horizons, and accepted thresholds of impact. The last one usually failed. The approach, explained in some detail in Nagy *et al.*, (2014b), shared many concepts, procedures, and goals with other approaches explained in section 3 such as the risk-based management and the scenario planning for climate change.

According to Moore *et al.*, (2013) "The process of developing scenarios gives scientists an opportunity to clearly articulate the potential consequences of uncertain drivers in a manner that empowers decision makers, rather than leaving them paralyzed with no clear path of action. Scenario planning is only as useful as the scenarios are plausible to the exercise participants. Without buy-in to the scenarios, scenario planning becomes a mere exercise in imagination". The questions usually discussed during scenario planning are focused on:

- The direction of change (increase or decrease?).
- The magnitude and threshold (How much? Is the impact affordable or not?).
- The rate of change/timing of impacts (How soon/ At what time of year will the change or event likely happen?).
- The interaction of climatic and non-climatic socio-economic, environmental, and technological drivers.

All available information was shared with experts from the academia (University of the Republic) and institutional stakeholders (Directorate of the Environment, Directorate of Aquatic Resources, and Municipal Governments) in a workshop held in March, 2012 (Nagy *et al.*, 2014c). Before the workshop was held, the Project communicated some results to institutional managers and scientist in order for them to make some inputs to the draft of adaptation management, scientific and/or monitoring measures. Thus, besides increasing confidence and awareness, it was possible to adjust the expectative to the institutional needs and implementation possibilities. During the workshop the Project's climate science and management experts analyzed climate threats and scenarios, identified vulnerabilities, participants. Without buy-in to the scenarios, scenario planning becomes a mere exercise in imagination". The questions usually discussed during scenario planning are focused on:

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During the workshop the Project's climate science and management experts analyzed climate threats and scenarios, identified vulnerabilities, and a list of best adaptation measures based on the international literature and local experience. The goals of the workshop were to:

1. Communicate scientific results and potential future management options.
2. Receive feedbacks from the attendants.
3. Increase awareness with regard to climate change and variability.
4. Involve those who wished to participate in the implementation of the process.

The results of GCMs' outputs, impact-ranking according to expert judgment (N= 8), and institutional practitioners (N=5), as well as the discussions during the meetings and the workshop were synthesized (Table 3).

Table 3 - Participatory climate scenario for adaptation planning. Expected changes are represented by symbols:not significant (=), increase (+), and decrease (-). Based on Escobar *et al.* (2004); Bidegain *et al.* (2005; 2011a, b; 2012); Camilloni & Bidegain (2005); Nagy *et al.* (2008 b, 2014a); Alves & Marengo (2010).

Tabela 3 - Cenário climático participativo para o planejamento da adaptação. As mudanças esperadas são representadas por símbolos: não significativo (=), aumento (+) e diminuição (-). Baseado em Escobar et al. (2004); Bidegain et al., (2005; 2011a, b; 2012); Camilloni & Bidegain (2005); Nagy et al. (2008 b, 2014a); Alves & Marengo (2010).

Climate variable	General change expected for 2030-50 / Relative size compared to already observed changes	Confidence level
River flow (total river inflow).	(= or +) in total annual river flow, but not uniform on both seasonal and interannual time-scales. Different patterns should be expected for both tributaries separately.	Low to Moderate
Temperature	(+) in annual mean, but not uniform on both seasonal and interannual time-scales. Likely (+) by 2030 and (++) by 2050 plus.	High to Very High
Rainfall (basin and local level)	(= or +) in total annual rainfall, but not uniform on time and geographic scales. Very likely lower than during 1971-2002 and likely reverting the slight (-) tendency since ca. 2004.	Low to Moderate
Sea-level	(+) in total annual SLR, but not uniform on both seasonal and interannual time-scales. Probably similar or greater than during 1971-2003 and greater than during 1997-2012 since probably 2015-20. Likely (++) by 2050 plus.	High to Very High
Winds	Unclear. (=or +) in average. Likely increase in South-Eastern (on-shore) wind and likely relatively (+) East-ward for 2030-50. Likely (= or +) than during 1961-90.	Moderate to High
Extreme events: River Flow	Unclear. (=or +) likely during spring-summer time for 2050, thus more impacts on most environmental issues. Likely (= or -) than during 1961-2012. Perhaps less than during 1997-2012, if not severe impacts are likely to occur.	Low to Moderate
Extreme events: Rainfall	Unclear. (= or +) likely during spring-summer time. Likely summer extreme rainfalls will impact beach water quality at Montevideo capital city without new "hard-engineering" adaptation measures.	Moderate
Extreme events: Storms	Likely (=or +) which will increasingly impact resources and infrastructure for 2030.	High to Very High

Alternative Scenarios

Some alternative scenarios with opposed drivers were developed for the Rio de la Plata and the Uruguayan coast, e.g. more or less river inflow, or more or less South-Easterly (on-shore) / North-Westerly (offshore) winds (Figure 6).

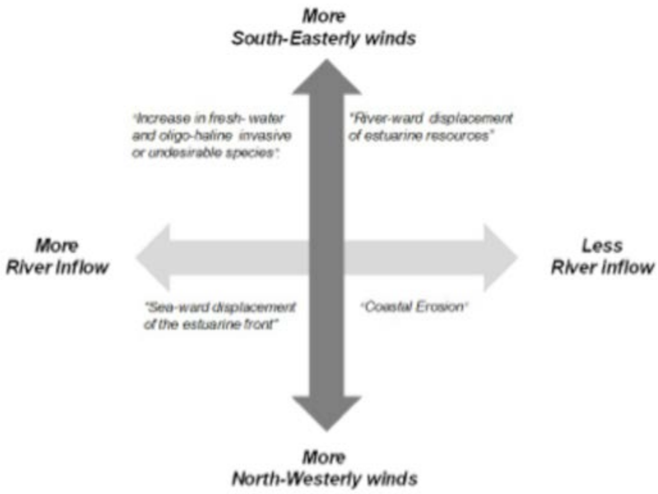

Figure 6 - The four climatic scenarios from the alternative futures of the Rio de la Plata estuarine waters and Uruguayan coast. Potential environmental impacts were chosen for each combination.

Figura 6 - Os quatro cenários climáticos para as alternativas futuras das águas estuarinas e da costa uruguaia de Rio de la Plata. Foram escolhidos, para cada combinação, os potenciais impactos ambientais.

According to Evans *et al*., (2013), this kind of approach becomes a risk-management research tool. Emphasis can be put on "what if" instead on a future uncertain time-frame. If a future was to be specified, it could be 2025, thus the outputs of GCMs for 2020-29 could be intercepted with long-term trend projections. In our experience stakeholders do not need "plausible" or "catastrophic" futures to be aware of the need of adaptation, but "realistic ones which can impact on them". Thus, (alternative) scenarios are tools to learn to adapt more than to foresee. An effective adaptation to an uncertain - but likely worse future - is better than a good forecast (if possible) without adaptation (adaptation deficit).

The use of "more and less" in figure 6 is based on the participatory scenarios (see Table 2) implying some degree of change which is both "perceived by stakeholders" and produce measurable significant effects in climatic and environmental records and processes, *e.g.*, coastal erosion, sandy-barriers opening, displacement of the estuarine front, changes in fishing season and catch, cyanobacterial blooms, and coliforms' survival.

7. Final Reflections

During this stage of building capacity to analyze and implement adaptation measures in coastal Uruguay many authors and local experiences have been consulted. Here, we emphasize on two - among several useful concepts - that describe the "essence of our feeling" on coastal climate adjustment and adaptation discussed along this article.

Firstly, the need of "adapting to variability before change" and "the analysis of preexisting adaptation strategies for climate variability is a proxy for future adaptation planning" (Butler & Coughaln, 2011).

Secondly, "persistent vulnerability to climate variability is a symptom of an adaptation deficit in socio-ecological systems" (Preston *et al*., 2013).

Living with increased climate variability in South-Eastern South America since the early 70s (the "ENSO era"), implies that both the expert and local knowledge are expressed through adjustment actions. All over the world and in Uruguay, the increase in extreme events has fostered climate awareness. Many of these events occurred during ENSO years. Going from reactive actions to negotiation and anticipatory planning which combines existing knowledge, information, and capacities with capacity building is still the overarching goal.

Adaptation efforts often cannot follow the increase in climate threats. The fact of not been able to (successfully) cope with current climate stressors is not a lesson to adapt to an uncertain future. However, we can learn from this failure.

Scientists (especially from physical domains) usually prefer top-down predictions with statistical uncertainty, whereas managers prefer some certainty, narrow range of values, and near-future time-horizons. The issue is that adaptation is a socio-political process and in order to reduce the adaptation deficit the best practitioners can do is to contribute to "grounded" science to fill the gap with management.

Robust trends are preferred by most stakeholders. They facilitate adaptation "buy in" (by stakeholders), especially if they are associated with long-standing socio-environmental problems related to climate drivers. The reverted trend prevailing since 1997, especially since 2003-04, is not strongly perceived among coastal scientists and managers yet. If it is to continue, it could affect the perception of future climate change, not of the need of a better understanding of the present and the near-future.

The incorporation of climate threats into policy and plans through the mix of top-down and bottom-up approaches allowed increasing stakeholders and decision-makers' capacities to implementing adaptation. This is due to the fact that the process focuses on the identification of specific, feasible, and flexible actions through negotiation, prioritization, and search of agreements and synergies among the institutional and local stakeholders in charge of the implementation phase.

The exchange between natural and social scientists with stakeholders and decision-makers increase mutual understanding, thus a "common language" can be used to planning adaptation. Thus, it is a learning by-doing experience intended to increase the feasibility and capacities for adaptation.

Thinking "alternative futures" is a task the academia and practitioners must incorporate, together with stakeholders, into the political agenda. A simple comprehensive near-future scenario was developed as a communication and research tool for adaptation planning based on science, expert-judgment, and expectations. It is not intended as an end product but as a way to explore "what if" in the future. This scenario can be transformed into axes of opposed drivers to explore, together with stakeholders, potential impacts under changing climate drivers. This type of participatory exercise should be a key component to building adaptation capacities at the national level.

Finally, the importance of the subject and of the obtained results in this article - as well as of the three previous ones - to integrated coastal zone management may be synthesized as follows:

- The mix of current coastal climatic threats and future climate change and sea-level rise (SLR) scenarios, because the latter are not usually considered in ICZM in Uruguay.
- The Project learned from ICZM experience the importance and the need of working with a multi-stakeholders and problem-solving.
- The development of participatory alternative futures where both scientific knowledge and stake-holders' perceptions and needs can be explored to prioritize actions.

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