CONCEPTUAL OVERVIEW

Regional Ocean Modeling for the Arabian Gulf – Desalination & Climate Change

Authors of this report are José Edson, Ilana Wainer, and Bruno Ferrero
Oceanography Institute at the University of Sao Paulo in Brazil.

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This goal of this study was to develop projections of regional changes in the Arabian Gulf due to the combined impact of climate change and an intensification of future desalination activities. To achieve this, a regional ocean model (ROM) was used that, on the one hand, could adequately capture local oceanographic processes and characteristics including sea surface temperature profiles, circulation patterns, fresher water influxes, balancing of ocean currents, and topographical features of the bottom of the Arabian Gulf. On the other hand, the ROM could represent the magnitude and properties of hot brine discharge from desalination units. The outputs generated by the modeling can be used in support of the other climate change impact, vulnerability and adaptation assessments.

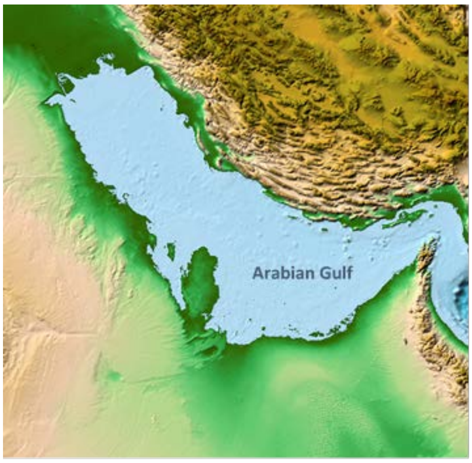


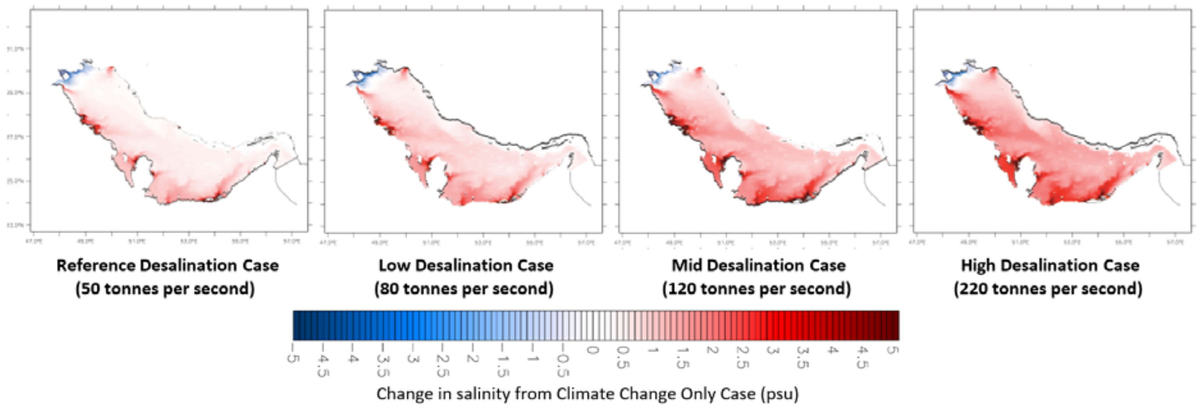
Figure 1 - Boundaries of the Arabian Gulf

Specifically, the focus was on the Arabian Gulf itself, a semi-enclosed, highly saline sea between latitudes 24°N and 30°N surrounded by a hyper-arid environment (see Figure 1). Its bathymetry shows large areas of shallow water (less than 10 metres deep) with a maximum depth of about 110 metres near central areas. Northwesterly Shamal winds affect Gulf waters in the winter, while southeasterly Shamal winds dominate in the summer. Such winds affect the Gulf's circulation patterns leading to seasonally stratified waters.

The environmental impacts of desalination are associated primarily with the waste stream that is discharged into the Arabian Gulf. This waste stream consists of hot brine, treatment chemicals, and other trace elements. The environmental impacts associated with such concentrated brine discharges include increasing levels of biocides, chlorination, and descaling chemicals. For the Arabian Gulf, this can lead to chronic toxicity and small-scale alterations to community structure in near-field marine environments, particularly for corals. Moreover, hot brine effluent from Reverse Osmosis plants can be up to 85 ppt and 50 ppt for Multi-stage flash units. As the effluent is heavier than seawater, it sinks to bottom and slowly circulates causing harm to sea grasses and other ecosystems on which a large range of aquatic life (e.g., dugongs) depend.

Under the combined influence of desalination and climate change, the Arabian Gulf will become even more highly stressed. Building off the regional ocean modeling effort that considered climate change only (for details see the regional ocean modeling Inspector) one future period was considered – 2040-2050. One greenhouse emission scenario was modelled that assumed a business-as-usual trajectory of global greenhouse gas emissions (i.e., RCP8.5). This is the more aggressive greenhouse gas emissions trajectory most like humankind's current trajectory, and as such, provides a useful basis by which to understand potential climate change implication for the Gulf. Several climatic variables were projected, including sea surface temperature, salinity, circulation dynamics, turbulence, and mixing processes. Several core research questions were addressed: 1) How will the high levels of socioeconomic growth projected for each country in the region affect the magnitude of brine discharges into the Gulf over time? 2) How are key Gulf physical properties affected by the middle of the 21st Century due to the combination of climate change and intensified desalination activities? And 3) To

Figure 2: Change in average bottom seawater salinity over and above Climate Change, 2040-2049



what extent does climate change potentially exacerbate the environmental impacts of future desalination activity?

Available computing resources limited the actual number of brine discharge points that could be effectively integrated into the regional ocean model. This is primarily due to the complexities involved in the integration of hyper-saline discharge from a set of desalination plants into a validated, fine-tuned, high-resolution regional ocean model in which climate change signals have been downscaled. Hence, the number and location of desalination plants were spatially reduced from 486 plants into fourteen (14) representative points whose annual brine discharges were collectively equivalent to the magnitude from all plants. These representative plants are referred to as “saline rivers”. These saline rivers were modeled as direct injections of hot brine into the Gulf. This modeling approach does not account for local effects in the immediate vicinity of the underwater brine discharge points. That is, only far-field modeling was undertaken (i.e., using a roughly 1 km resolution). To account for uncertainty, brine discharge scenarios of 50, 80, 120, and 220 tonnes per second were modeled. By 2050, the results show that the combined impact of desalination will significantly impact both temperature and salinity throughout the Gulf. An excerpt of the modeling results is illustrated in Figure 2 which shows the impact on average bottom salinity for the four scenarios of future desalination activity, over and above climate change impacts.

A full technical discussion of the results as well as a set of visualizations (i.e. maps and animations) of the outputs can be accessed at AGEDI's Climate Change Inspector website (http://www.ccr-group.org/desalination). The large output databases are also available on the Inspector for download.