AGEDI
مبادرة أبوظبي العالمية للبيانات البيئية
Abu Dhabi Global Environmental Data Initiative

an initiative of

UNEP

هيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

LOCAL, NATIONAL, REGIONAL CLIMATE CHANGE PROGRAMME

DESALINATION & CLIMATE CHANGE

Companion Briefing

Climate Change Research Group

UNIVERSIDADE DE SÃO PAULO
IO
Instituto Oceanográfico

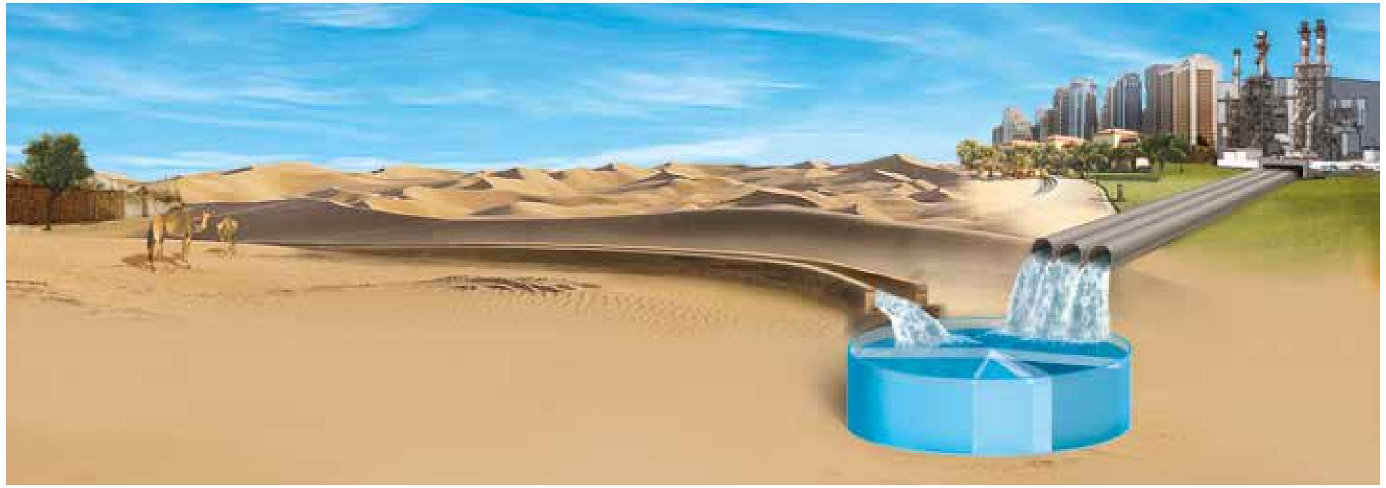
This Companion Briefing has been prepared by Jose Edson, Bruno Ferrero and Ilana Wainer of the Oceanography Institute at the University of Sao Paulo (Brazil).

Published by: Abu Dhabi Global Environmental Data Initiative (AGEDI), 2016.

Recommended Citation: AGEDI 2016.
Companion Briefing Desalination and Climate Change.
LNRCCP. CCRG/IO.

AGEDI and EAD promote environmentally sound practices globally and in their own activities. This publication is printed on ecological paper. Our distribution policies aim to reduce our carbon footprint.

Introduction



This Companion Briefing aims to offer broad-level conclusions from regional ocean model runs as reported in the Desalination & Climate Change Draft Technical Report (Edson, et. al. 2016). A team from the Oceanography Institute at the University of Sao Paulo undertook the modelling. The study projected mid-21st Century impacts on Gulf temperature and salinity due to climate change and desalination. The conclusions highlighted below are limited to a presentation of high-level trends relative to future average and maximum conditions throughout the Gulf.

For a discussion of the oceanographic processes underlying these trends (e.g. inflow/outflow circulation dynamics through the Hormuz Straits), the reader is kindly referred to the accompanying Technical Report where explanations for each observed trend are provided, albeit at a level of technical detail most suitable for ocean modelers.

Background

The Arabian Gulf has historically been one of the most stressed marine environments on earth.

It is a semi-enclosed, highly saline sea between latitudes 24°N and 30°N surrounded by a hyper-arid environment. The Arabian Gulf is characterized by salty ocean water inflow from the Gulf of Oman along the Iranian coastline and limited freshwater inflow via the Tigris, Euphrates, and Karun rivers at the delta of the Shatt al Arab in Iraq. Under climate change alone, the Arabian Gulf will become even more highly stressed, with significant increases in temperature throughout, coupled with zones of large salinity increases (Edson, et. al. 2015).

The Arabian Gulf is also a region of intense seawater desalination activity.

Today, much of the freshwater needs in the Arabian Peninsula region are met by the desalination of seawater. Desalination processes separate seawater into freshwater which is then distributed to meet the freshwater demands of households, businesses, amenities, and industry. As an outcome of the process, there is highly saline and hot wastewater discharged into the Arabian Gulf. Across the Arabian Peninsula, there are currently about 2,241 desalination plants. Of these, there are 982 plants corresponding to the eight countries (i.e. Bahrain, Iraq, Iran, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE) which depend on seawater as the feedstock. And of these, there are 486 plants accounting for over 14 million cubic meters per day of capacity that discharge brine by products to the Arabian Gulf.

The Desalination & Climate Change study was undertaken in two phases.

In the first phase, a Regional Ocean Model System (ROMS) was developed using a 1.1 km spatial resolution, validated to reproduce observed conditions in the Gulf. This model was then used to dynamically downscale outputs from a well-accepted global circulation model, based on Representative Concentration Pathway 8.5 (i.e. the IPCC's "business as usual" scenario), for the mid- and late-21st Century periods. Anthropogenic sources of salinity to the Gulf (i.e. brine discharges from desalination) were ignored. In the second phase, the validated Arabian Gulf region ocean model under climate change was used to explore the impact of brine discharges on overall temperature and salinity throughout the Gulf. A "saline river" approach was used to simulate the spatial distribution of future hot brine discharges to the Gulf. Four brine discharge scenarios were modeled to bracket uncertainty; 50, 80, 120, and 220 tonnes per second. These and other aspects of the regional modelling are described in Edson et al (2016).

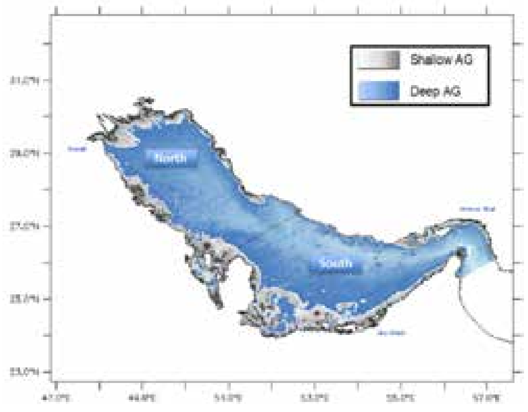


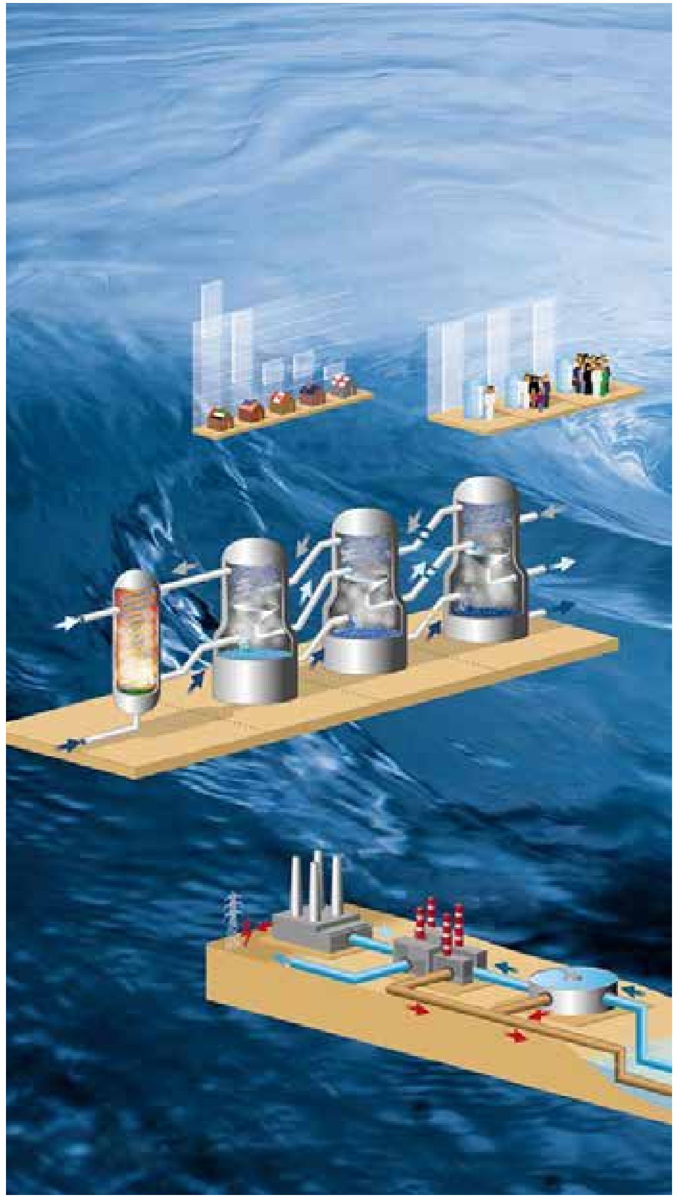
Figure 1: Key areas Arabian Gulf for regional modelling

Spatial context

The regional ocean modelling conducted in the second phase suggest that desalination activities under climate change will impact temperature and salinity levels throughout the Gulf.

An overall summary of average and maximum temperature and salinity for each brine discharge scenario was developed relative to the spatial configuration shown in Figure 1 and described in the bullets below.

- **Northern Gulf:** This region extends from the Shatt-al Arab in Iraq to just south of Jubail in Saudi Arabia.
- **Southern Gulf:** This region extends from the southern parts of Bahrain throughout the Straits of Hormuz to the northern area of the Gulf of Oman
- **Shallow areas:** These areas refer to shallow water less than 20 meters in depth. These areas are shown in grey on the Figure 1. Within shallow areas, the focus is on the surface layers (top 30 cm) and bottom layers (lowest 30 cm).
- **Deep areas:** These areas refer to deeper waters greater than 20 meters in depth. These areas are shown in blue on the Figure 1. Within deep areas, the focus is also on the surface and bottom layers.

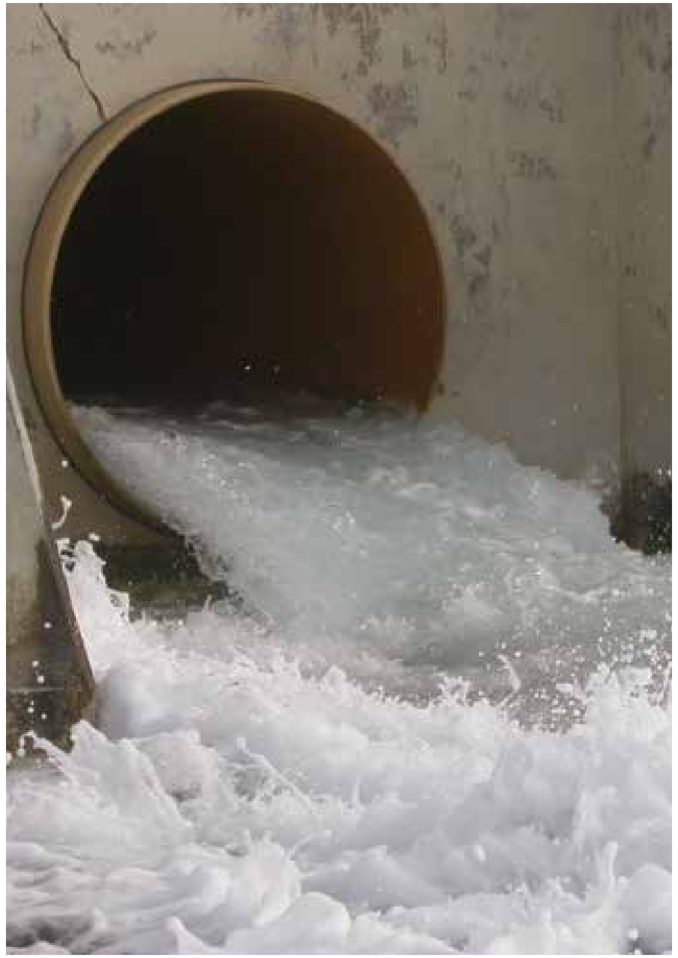


Caveats and limitations

It is important to note that there are several caveats and limitations associated with the underlying regional ocean modelling effort.

These are outlined in the bullets below. Combined, these caveats and limitations introduce a not unexpected level of uncertainty into the results. Nevertheless, while uncertainty levels can be reduced with finer levels of resolution and additional data ground-truthing, there is a high level of confidence in overall direction of the conclusions and their validity for use in subsequent marine biodiversity assessments, policy/utility planning, climate change adaptation planning, as well as inputs for brine discharge mitigation efforts.

- **Brine discharge quantities:** Future quantities of saline discharges into the Gulf were estimated on the basis of past trends in desalination technology and desalinated water demand. Projected brine discharges in 2050 were based on four plausible scenarios governed by economic growth, impact of water conservation policies, and relative shares of desalinated groundwater consumption.
- **"Saline river" approach:** From a modelling perspective, the optimal number of brine discharge points (or "saline rivers") that could be efficiently modelled was fifteen (15). They were spaced uniformly across the Gulf to avoid near-field microphysics and/or anomalies. The total magnitude of brine discharge was distributed across the saline rivers consistent with projected national levels of desalinated water supply.
- **Near-field modelling:** There was no near field modelling of the immediate zones of the brine discharge plume. A much finer resolution model (less than 100 meters) would have been required to resolve the full spectra of mixing parameters, together with much greater computation resources.



Overall summary of results

The results of average and maximum temperature and salinity are summarized in Tables 1 and 2, respectively, for the mid-21st Century period.

A total of six (6) scenario results are provided. For Phase 1 modelling (i.e. climate change only), results for the first two (2) scenarios correspond to historical conditions and climate change. For Phase 2 modelling (i.e. desalination & climate change), results for the remaining four (4) desalination scenarios are included. In the next few sections, some of the key trends that are evident from an examination of these summary results are provided.

Table 1: Summary of temperature modelling results for key areas of the Arabian Gulf (degrees Celsius)

Regional model run	Scenario #	Time period	GHG emissions	Brine discharge rate to Arabian Gulf (tonnes per second)	Arabian Gulf South Region								Arabian Gulf North Region							
					shallow area				deep area				shallow area				deep area			
					surface		bottom		surface		bottom		surface		bottom		surface		bottom	
					ave	max	ave	max	ave	max	ave	max	ave	max	ave	max	ave	max	ave	max
Historical - No climate change	1	1985-2005	NA	0	27.0	41.4	27.2	46.4	27.3	37.2	26.5	39.4	24.3	44.5	25.2	48.9	25.9	37.0	25.2	40.2
Mid 21st Century - No climate change; No desalination	2	2040-2049	RCP8.5	0	27.7	42.5	27.7	42.7	28.0	38.9	26.6	38.9	25.1	40.1	25.1	40.2	26.6	37.6	25.6	37.6
Mid 21st Century - Climate change; Reference desalination	3	2040-2049	RCP8.5	50	27.7	42.6	27.9	49.2	28.0	38.6	27.2	41.9	25.1	45.6	25.9	49.9	26.7	39.0	26.0	41.0
Mid 21st Century - Climate change; Low desalination	4	2040-2049	RCP8.5	80	27.7	42.6	28.0	48.3	28.0	38.7	27.4	41.7	25.1	46.1	26.1	50.9	26.7	39.2	26.1	41.5
Mid 21st Century - Climate change; Medium desalination	5	2040-2049	RCP8.5	120	27.7	42.9	28.1	46.7	28.0	38.4	27.7	42.8	25.2	46.0	26.3	51.7	26.7	39.4	26.3	41.8
Mid 21st Century - Climate change; High desalination	6	2040-2049	RCP8.5	220	27.7	42.6	28.1	46.8	28.1	38.5	28.0	42.9	25.2	46.0	26.5	51.8	26.8	39.4	26.5	41.6

Table 2: Summary of salinity statistical results for key areas of the Arabian Gulf (psu)

Regional model run	Scenario #	Time period	GHG emissions	Brine discharge rate to Arabian Gulf (tonnes per second)	Arabian Gulf South Region								Arabian Gulf North Region							
					shallow area				deep area				shallow area				deep area			
					surface		bottom		surface		bottom		surface		bottom		surface		bottom	
					ave	max	ave	max	ave	max	ave	max	ave	max	ave	max	ave	max	ave	max
Historical - No climate change	1	1985-2005	NA	0	27.0	41.4	27.2	46.4	27.3	37.2	26.5	39.4	24.3	44.5	25.2	48.9	25.9	37.0	25.2	40.2
Mid 21st Century - No climate change; No desalination	2	2040-2049	RCP8.5	0	27.7	42.5	27.7	42.7	28.0	38.9	26.6	38.9	25.1	40.1	25.1	40.2	26.6	37.6	25.6	37.6
Mid 21st Century - Climate change; Reference desalination	3	2040-2049	RCP8.5	50	27.7	42.6	27.9	49.2	28.0	38.6	27.2	41.9	25.1	45.6	25.9	49.9	26.7	39.0	26.0	41.0
Mid 21st Century - Climate change; Low desalination	4	2040-2049	RCP8.5	80	27.7	42.6	28.0	48.3	28.0	38.7	27.4	41.7	25.1	46.1	26.1	50.9	26.7	39.2	26.1	41.5
Mid 21st Century - Climate change; Medium desalination	5	2040-2049	RCP8.5	120	27.7	42.9	28.1	46.7	28.0	38.4	27.7	42.8	25.2	46.0	26.3	51.7	26.7	39.4	26.3	41.8
Mid 21st Century - Climate change; High desalination	6	2040-2049	RCP8.5	220	27.7	42.6	28.1	46.8	28.1	38.5	28.0	42.9	25.2	46.0	26.5	51.8	26.8	39.4	26.5	41.6

Average temperature trends

The average temperature impacts on the Arabian Gulf from climate change and desalination are illustrated in Figure 2.

A summary of key observations is offered in the bullets below the figure.

- In surface layers throughout shallow and deep areas of the Gulf, climate change represents the overwhelming majority of the impact on average temperature. In the southern Gulf region, climate change accounts for about 95% of the roughly 0.8°C increase in average temperature, while accounting for 89% to 95% in the northern region.

- In bottom layers throughout shallow and deep areas of the southern Gulf, desalination dominates the impact on temperature. Desalination accounts for between 27% and 53% of the roughly 1°C increase in average temperature in shallow areas, across all brine discharge rate scenarios. In deep areas, desalination accounts for between 41% and 95% of the roughly 1.4°C increase in average temperature.

- In bottom layers throughout shallow and deep areas of the northern Gulf, desalination represents the overwhelming majority of the impact on average temperature. Desalination accounts for between 41% and 95% of the roughly 1.4°C increase in average temperature in shallow areas, across all brine discharge rate scenarios. In deep areas, desalination accounts for all of the up to 1.5°C increase in average temperature.

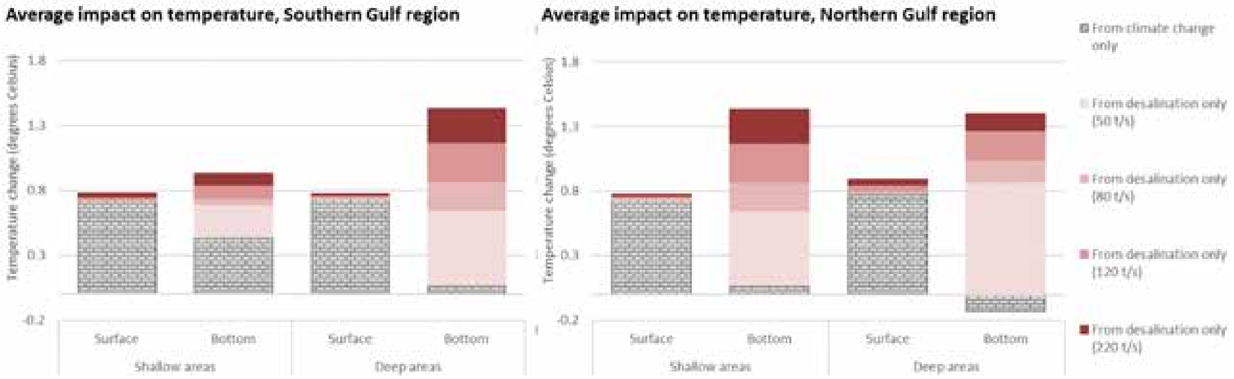


Figure 2: Average temperature impacts in the Arabian Gulf from climate change and desalination

Maximum temperature trends

The maximum temperature impacts on the Arabian Gulf from climate change and desalination are illustrated in Figure 3.

A summary of key observations is offered in the bullets below.

- Desalination impacts on maximum temperatures far exceed those on average temperatures. This is most evident for surface layers in deep areas of the Northern Gulf where maximum temperature increases from desalination are about 6.0°C compared to only a 0.1°C average temperature increase for the same area, or roughly 60 times greater. This is also evident for bottom layers in deep areas of the Southern Gulf where the maximum temperature increase from desalination is about 3 times greater than the average increase; 4.1°C average temperature increase compared to only a 1.4°C average temperature increase.

- In surface layers in the Southern Gulf, climate change represents the overwhelming majority of the impact on maximum temperature. In this region, climate change accounts for about between 74% (1.0°C) and 91% (1.7°C) of the total increase in maximum temperature.

- In bottom layers throughout shallow and deep areas of the Southern Gulf, desalination represents the entire impact on maximum temperature. Under climate change, maximum temperatures actually decrease in bottom layers through the Southern Gulf. With desalination, maximum temperatures are projected to rise up to 6.6°C and 4.2°C in shallow and deep areas, respectively.

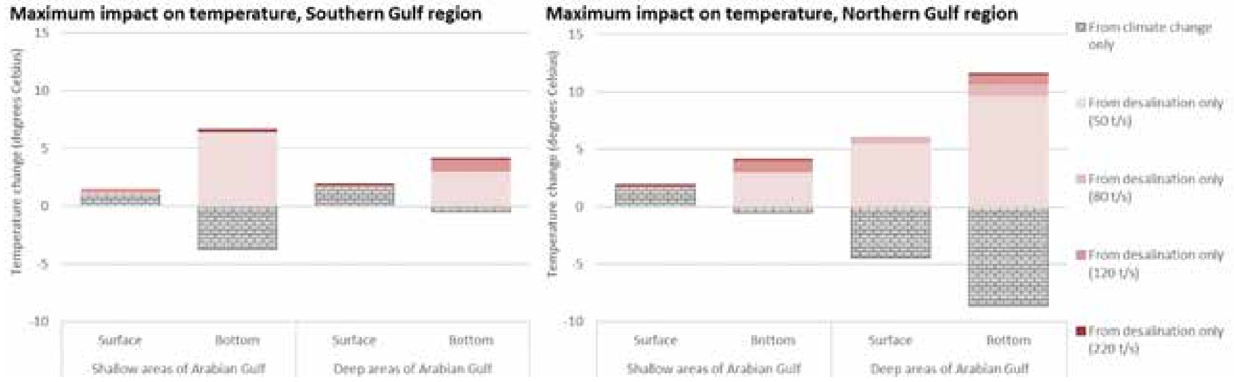


Figure 3: Maximum temperature impacts in the Arabian Gulf from climate change and desalination

- In bottom layers throughout deep areas of the Northern Gulf, desalination represents the entire impact on maximum temperature. Under climate change, maximum temperatures actually decrease. With desalination, maximum temperatures are projected to rise up to 4.2°C and 11.6°C in shallow and deep areas, respectively.

- In surface layers in the Northern Gulf, the impact of desalination shows mixed results. In shallow areas, climate change represents the overwhelming majority of the increase in maximum temperature, 1.7°C or 91%. In deep areas, maximum temperatures actually decrease under climate change, whereas maximum temperatures increase by up to 6.0°C due to desalination activities.

Average salinity trends

The average salinity impacts on the Arabian Gulf from climate change and desalination are illustrated in Figure 4.

A summary of key observations is offered in the bullets below.

- In shallow areas throughout surface and deep layers of the Northern and Southern Gulf, desalination represents the entire impact on average salinity. Under climate change, average salinity actually decreases. Depending on the brine discharge rate scenario, average salinity is projected to rise between 1.1 and 2.6 psu in the Southern Gulf and between 0.6 and 1.6 psu in the Northern Gulf.

- In bottom layers throughout deep areas of the Northern and Southern Gulf, desalination represents the entire impact on average salinity. Under climate change, average salinity actually decreases. With desalination, average salinity is projected to rise up to between 0.6 and 1.6 psu in the Southern Gulf across the range of desalination scenarios. In the Northern Gulf, average salinity is projected to rise up to between 0.1 and 1.2 psu.

- In surface layers throughout deep areas of the Northern and Southern Gulf, the impact of desalination shows mixed results. In the Southern Gulf, desalination represents the entire increase on average salinity (0.2 to 0.6 psu) as average salinity actually decreases under climate change. In the Northern Gulf, desalination represents between 0 and 1.4 psu (0% to 42%).

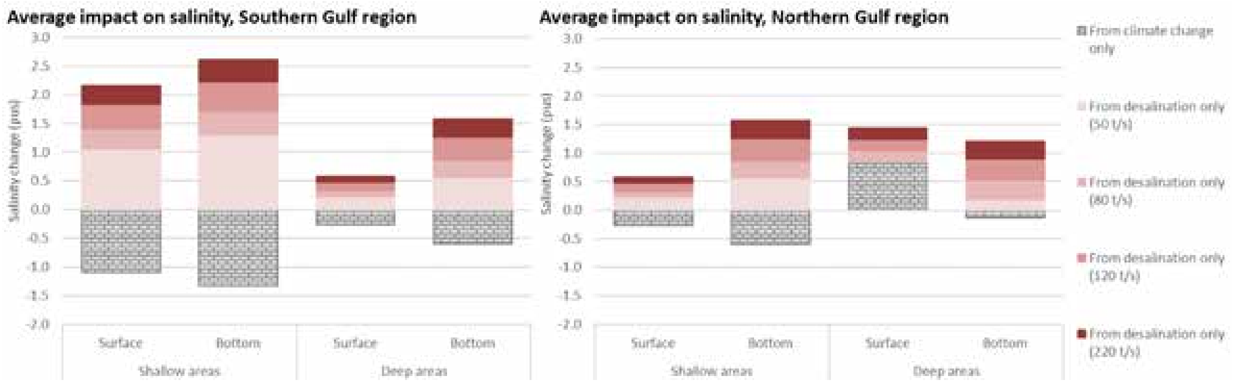


Figure 4: Average salinity impacts in the Arabian Gulf from climate change and desalination

Maximum salinity trends

The maximum salinity impacts on the Arabian Gulf from climate change and desalination are illustrated in Figure 5.

A summary of key observations is offered in the bullets below.

- In surface and bottom layers throughout shallow and deep areas of the Northern and Southern Gulf, desalination represents the entire impact on maximum salinity. Under climate change, maximum salinity actually decreases. With desalination, maximum salinity is projected to rise from 5.5 psu in the lowest brine discharge scenario up to 16.5 psu in the highest brine discharge scenario.
- Desalination impacts on maximum salinity far exceed those on average salinity. This is evident throughout all regions of the Gulf. The ratio of maximum to average salinity under the highest brine discharge scenario ranges from 6 to 27. This is equivalent to a range in maximum salinity increase from 14.8 to 16.5 psu.

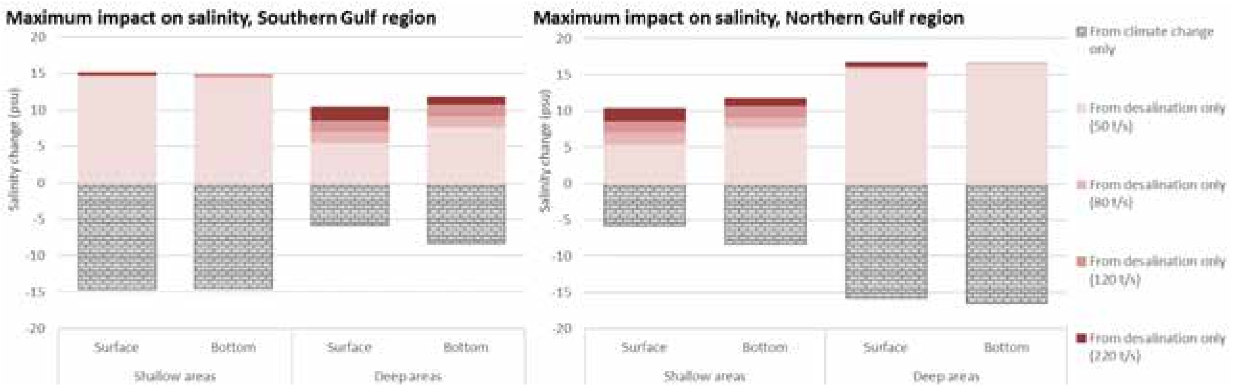


Figure 5: Maximum salinity impacts in the Arabian Gulf from climate change and desalination

- Throughout the Gulf, the greatest impact on maximum salinity is associated with the lowest brine desalination scenario.

✓ For shallow areas in the Southern Gulf, about 95% of the impact on maximum salinity is due to an average brine discharge rate of 50 tonnes per second. Even higher shares are evident for deep areas in the Northern Gulf for the same scenario. For both of these regions, salinity increases by about 0.3 psu for every increase of 1 tonne per second of brine discharge, up to 50 tonnes per second; above this discharge rate (i.e. between 50 and 220 tonnes per second) salinity increases by only 0.003 psu for every increase of 1 tonne per second of brine discharge.

✓ For deep areas in the Southern Gulf, between 53% and 66% of the impact on maximum salinity is due to an average brine discharge rate of 50 tonnes per second. Similar shares are evident for shallow areas in the Northern Gulf for the same scenario. For both of these regions, salinity increases between 0.11 and 0.15 psu for every increase of 1 tonne per second of brine discharge, up to 50 tonnes per second; above this discharge rate (i.e. between 50 and 220 tonnes per second) salinity increases by a range of only 0.02 to 0.03 psu for every increase of 1 tonne per second of brine discharge.

References

Edson, J, Wainer, I., and Ferrero, B, 2015. "Regional Ocean Modelling: A Numerical Study of the Impact of Climate Change on the Arabian Gulf", Final Report for AGEDI's Local, National, and Regional Climate Change Programme

Edson, J, Wainer, I., and Ferrero, B, 2016. "Desalination & Climate Change: Draft Technical Report from AGEDI's Local, National, and Regional Climate Change Programme"

About

AGEDI
مبادرة أبوظبي العالمية للبيانات البيئية
Abu Dhabi Global Environmental Data Initiative

an initiative of: بمبادرة من

UNEP

هيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

AGEDI

Under the guidance and patronage of His Highness Sheikh Khalifa bin Zayed Al Nahyan, President of the United Arab Emirates, the Abu Dhabi Global Environmental Data Initiative (AGEDI) was formed in 2002 to address responses to the critical need for readily accessible, accurate environmental data and information for all those who need it.

With the Arab region as a priority area of focus, AGEDI facilitates access to quality environmental data that equips policy-makers with actionable, timely information to inform and guide critical decisions. AGEDI is supported by Environment Agency – Abu Dhabi (EAD) on a local level, and by the United Nations Environment Programme (UNEP), regionally and internationally.

For more information, visit www.agedi.org.

The Environment Agency-Abu Dhabi

The Environment Agency – Abu Dhabi (EAD) was established in 1996 to preserve Abu Dhabi's natural heritage, protect our future, and raise awareness about environmental issues. EAD is Abu Dhabi's environmental regulator and advises the government on environmental policy. It works to create sustainable communities, and protect and conserve wildlife and natural resources. EAD also works to ensure integrated and sustainable water resource management, to ensure clean air and minimize climate change and its impacts.

For more information, visit www.ead.ae.

Climate Change Research Group

CCR Group

Climate Change Research Group (CCR Group) is a sustainable development research and consultancy firm focused on the intersection of energy, climate and development. Our network of specialists works with international development organizations, national and local governments, as well as non-governmental institutions to formulate policy frameworks, technical assessments and capacity building programmes.

Since CCR Group's founding in 2009, we have lead projects across Africa, the Middle East, Eastern Europe, Asia and the Americas. Because each client faces a unique set of challenges based on local context, we have experience developing strategies for multiple issues areas within sustainable development. Thematic issue areas and services for CCR Group include: Climate Change Adaptation Strategies; Greenhouse Mitigation Analysis; Climate Change & Disaster Risk Management; Climate Change, Agriculture & Food Security; Climate Change & Water Security; Climate Change & Public Health; Power Supply & Renewable Integration Modelling; Air Pollutant & Greenhouse Gas Emission Scenarios Modelling; and Capacity Strengthening Programmes.

For more information, visit www.ccr-group.org.

All reports and resources are available for download at www.agedi.org and on our Climate Change Inspectors Online Portal, http://www.ccr-group.org/cc-inspectors

LNRClimateChange@ead.ae

AGEDI
مبادرة أبوظبي العالمية للبيانات البيئية
Abu Dhabi Global Environmental Data Initiative

an initiative of

UNEP

هيئة البيئة - أبوظبي
Environment Agency - ABU DHABI

Abu Dhabi Global Environmental Data Initiative (AGEDI)
P.O Box: 45553
Al Mamoura Building A, Murour Road
Abu Dhabi, United Arab Emirates

Phone: +971 (2) 6934 444
Email : info@AGEDI.ae

AGEDI.org