ICCE 2018

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The State of the Art and Science of Coastal Engineering

Effects of Desalination on Hydrodynamic Process in Persian Gulf

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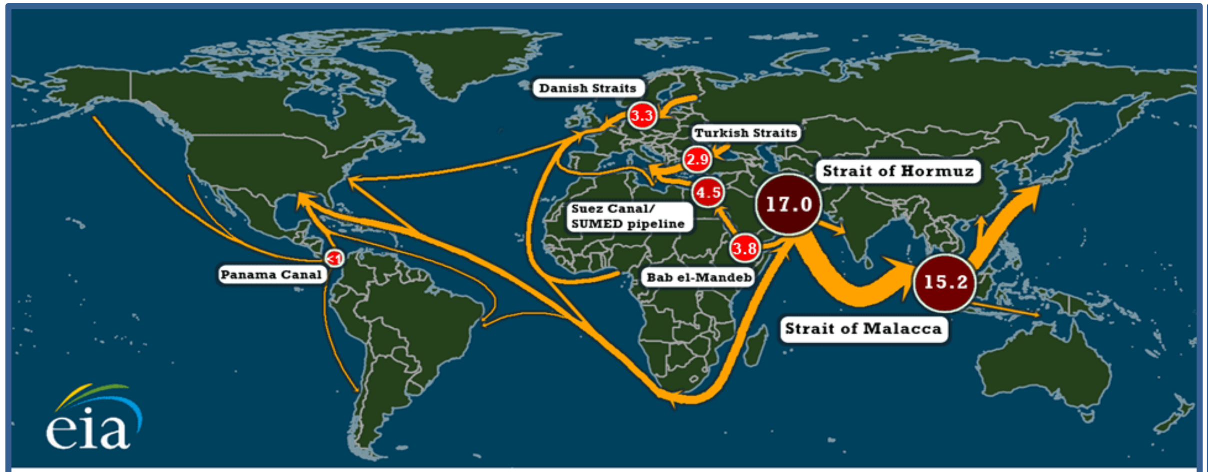
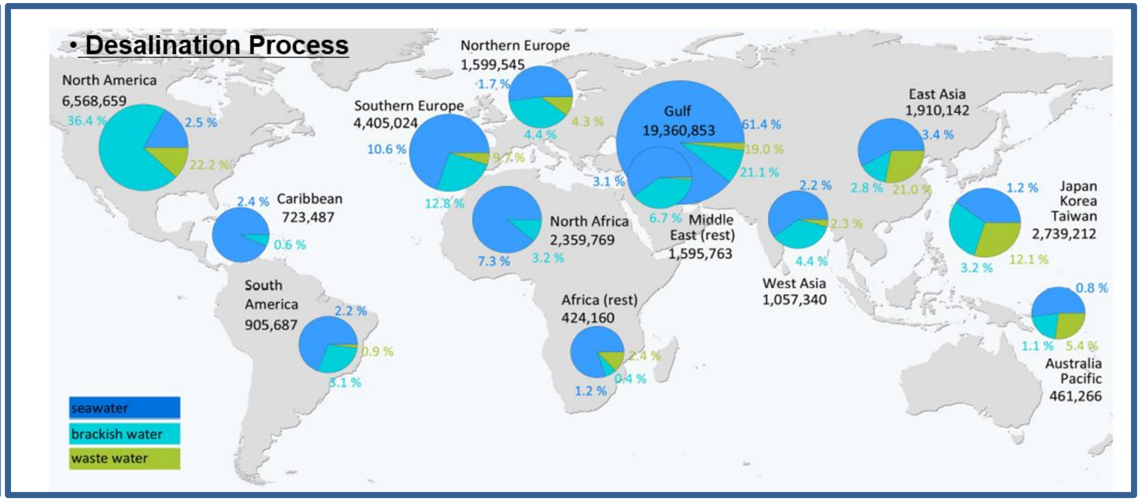
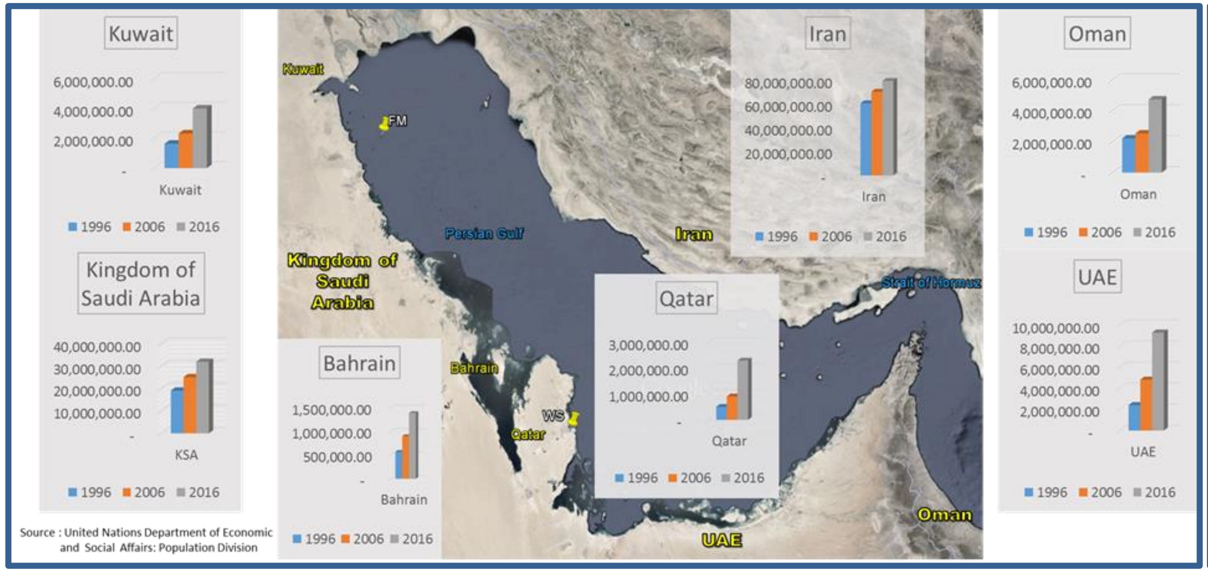
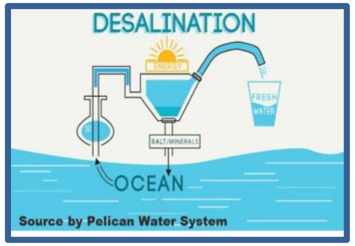
BACKGROUND



All estimates in million barrels per day. Includes crude oil and petroleum products. Based on 2013 data.







BACKGROUND

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Main Concerns

Other Impacts

Chemicals

Hopner and Windelberg (1997)

Von Medeazza (2005)

Economic Issue

Purnama et al. (2005)

Sheppard et al. (2010)

Land and Energy Uses

Al Barwani and Purnama (2008)

Bleninger and Jirka (2010)

Bleninger and Jirka, 2010
: Plant's location and production rate
Effluent recirculation back to intake
Produce low quality and efficient

Concentrate Discharge

At or Near Point of Discharge

Von Medeazza (2005)

Cooley et al. (2006)

Lattemann and Hopner (2008)

Dupavillon and Gillander (2009)

Salinity & Temperature increase

Mickley (1995): Sali (15%) / 5-15°C

Talavera and Ruiz (2001): 5 ppt (10m),
2.5 ppt (20m), 1 ppt (30m)

Einav et al. (2002): 4 ppt

Purnama et al. (2005): 0.06 ppt

Verdier (2011): high 2 ppt and more

Talavera and Ruiz (2011): 2 ppt

Dawoud and Al Mulla (2012): 0.005-0.01 ppt

Uddin (2014): 0.06 ppt

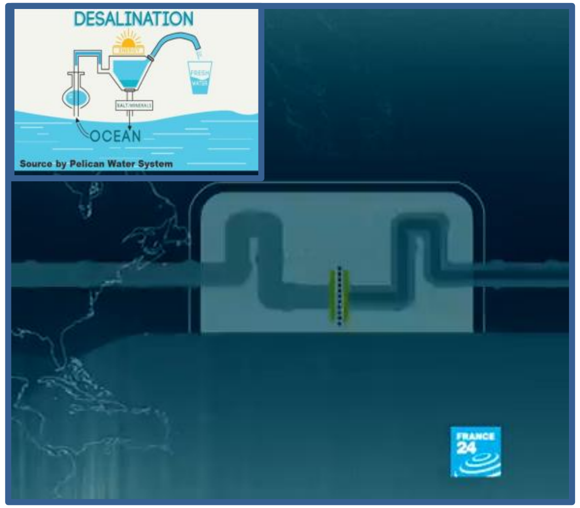
Alosari and Pokavanich (2017): 2 ppt, 3°C

Intake Water System

Cooley et al. (2006)

Lattemann and Hopner (2008)

Lattemann (2010)



Modeling Study

Modeling Study

Purnama et al. (2005): Math. Model

Bleninger (2006)

Bleninger & Jirka (2010): Delft3D+COMIX

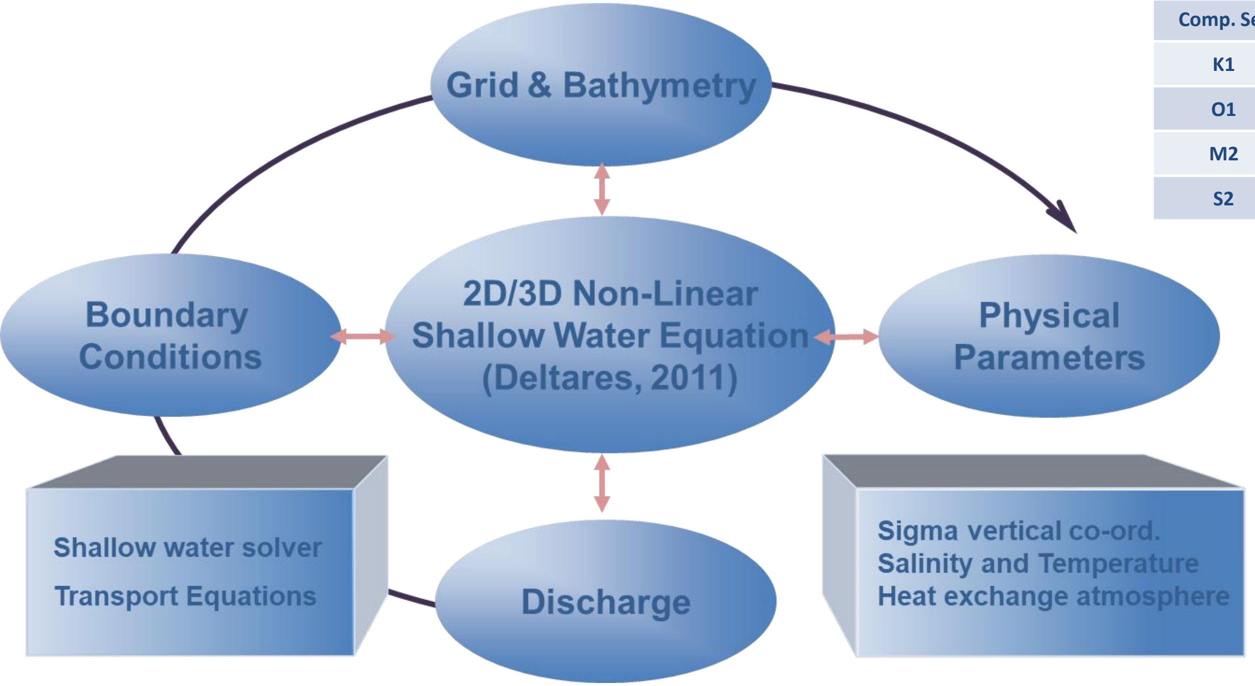
Al Barwani and Purnama (2008)
: Math. model

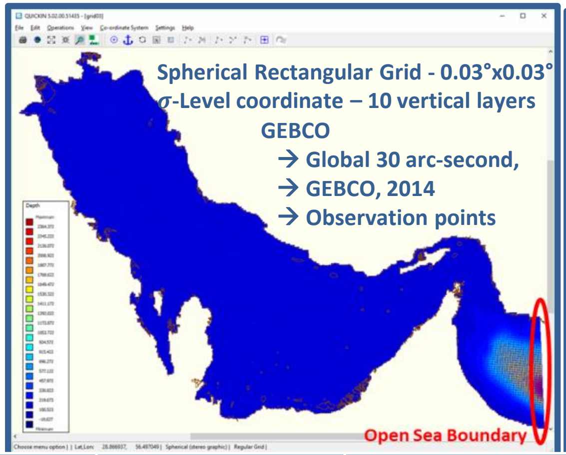
Rodrigo et al. (2011): Physical model

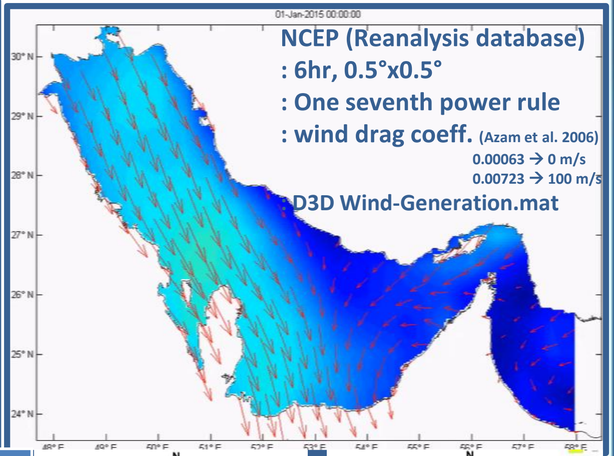
Alosari and Pokavanich (2017): Delft3D

MODELING SYSTEM

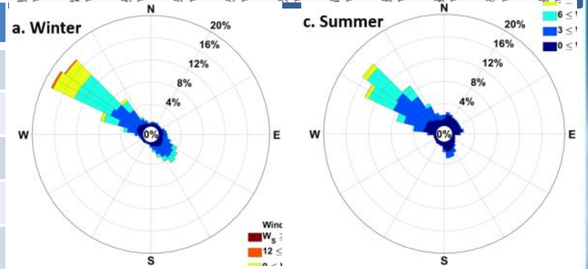
DELFT3D-FLOW Hydrodynamic Module

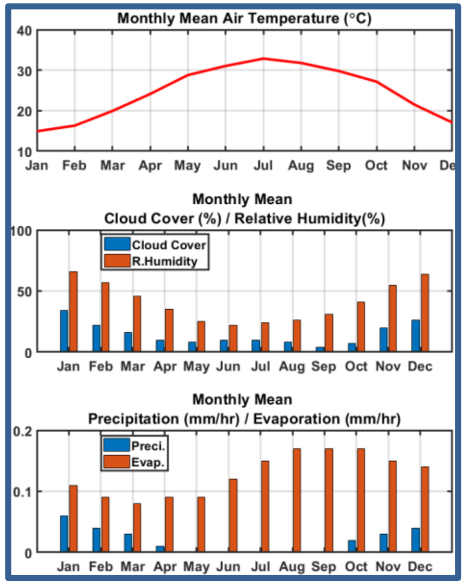






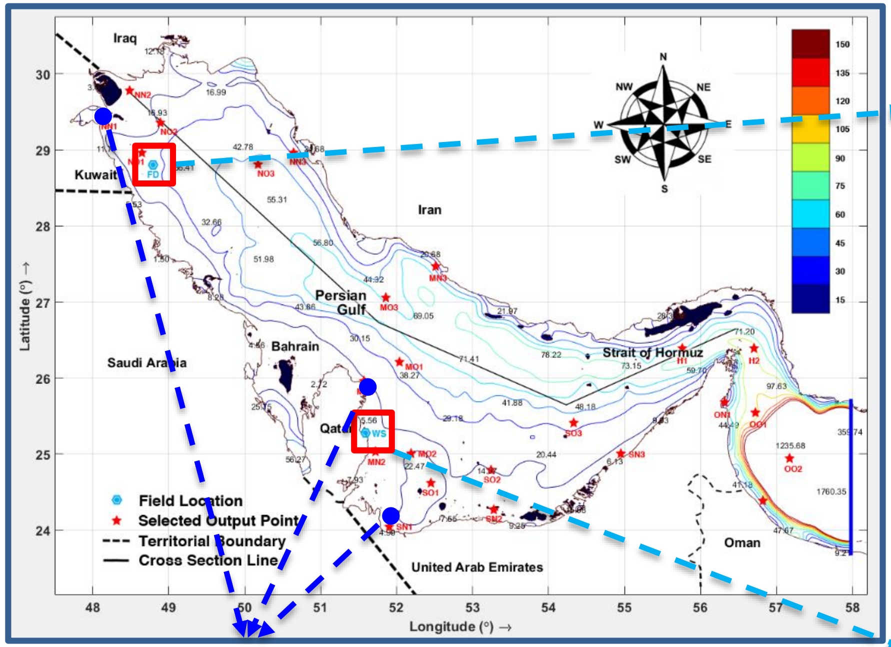
Location	Open-Sea Boundary A		Open-Sea Boundary B	
Comp. Set	Amp(m)	Phase(◦)	Amp(m)	Phase(◦)
K1	0.383	340.19	0.386	339.77
O1	0.201	347.16	0.206	342.36
M2	0.657	158.33	0.675	156.87
S2	0.253	189.92	0.261	189.13

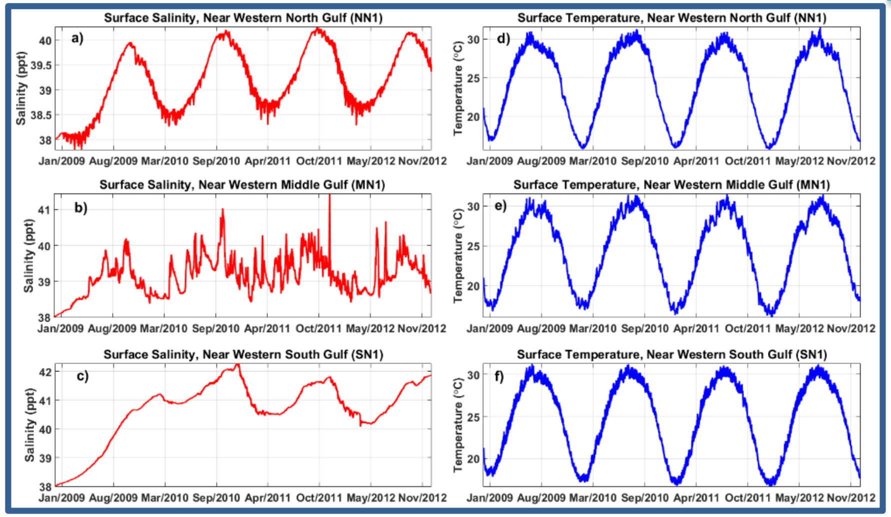


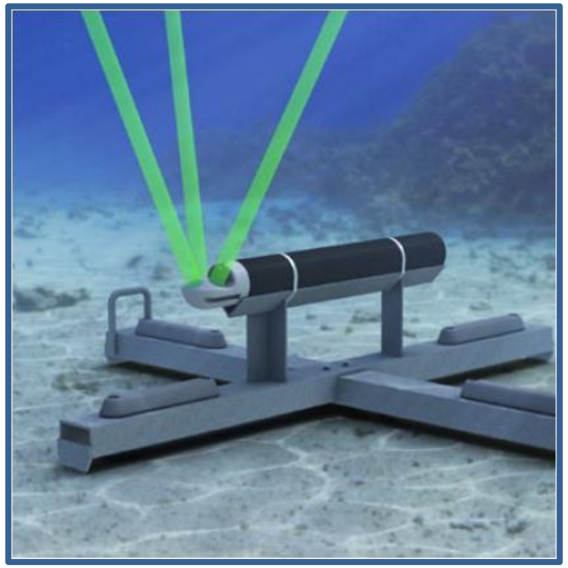


Gravity	Roughness (Manning)	Background horizontal viscosity / diffusivity
9.81 m/s²	U: 0.018 / V: 0.01	15 m²/s / 15 m²/s
Water Density	Water Surface Area	Secchi depth
1026 kg/m³	$2.4e^{+11}$ m²	2 m
Air Density	Sky cloudness	Dalton / Stanton
1 kg/m³	0%	0.001

MODELING SYSTEM <u>Model Validation</u>







Field Deployment #1
ADCP-bottom framed

TAMUG Microstructure Group, in 2013

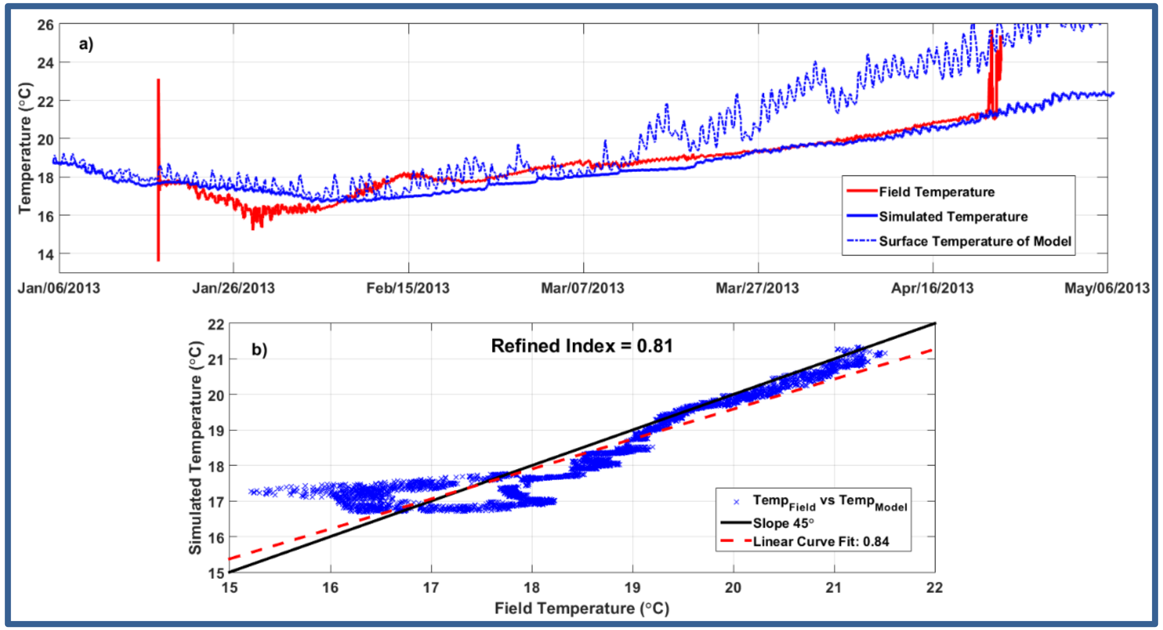
- 28.85°, 48.79° (Lat/Lon), offshore Kuwait
- <u>Currents</u> (m/s) / <u>Temperature</u> (at bottom, °C)
- Jan, 17th to Apr, 22nd , 2013
- Depth of field deployment: 25-26 m
- 3 min data intervals

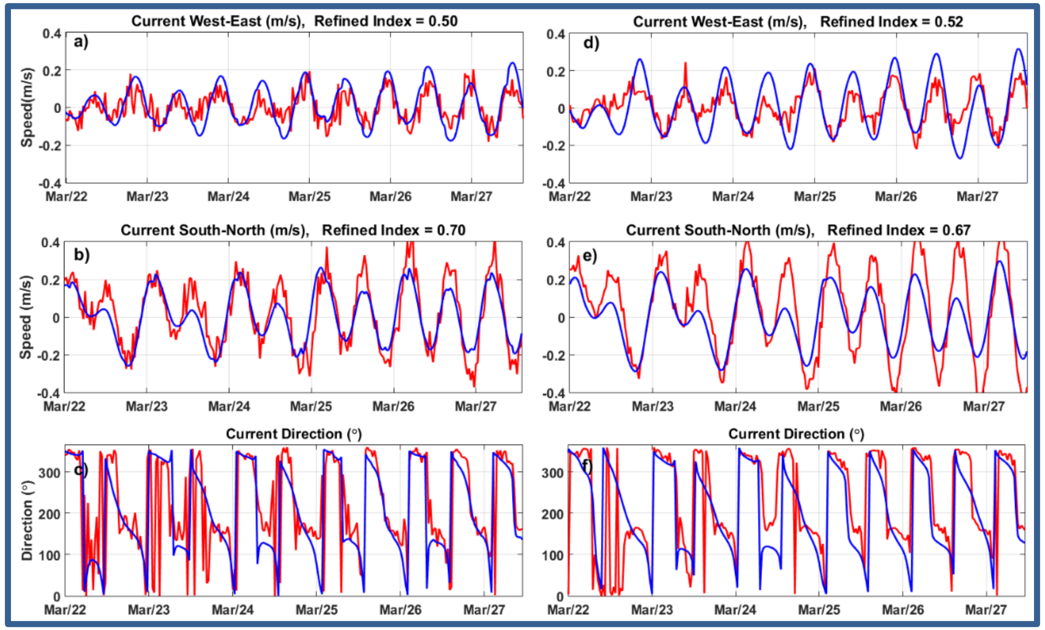
Weather Station #2
Historic data for OTBD

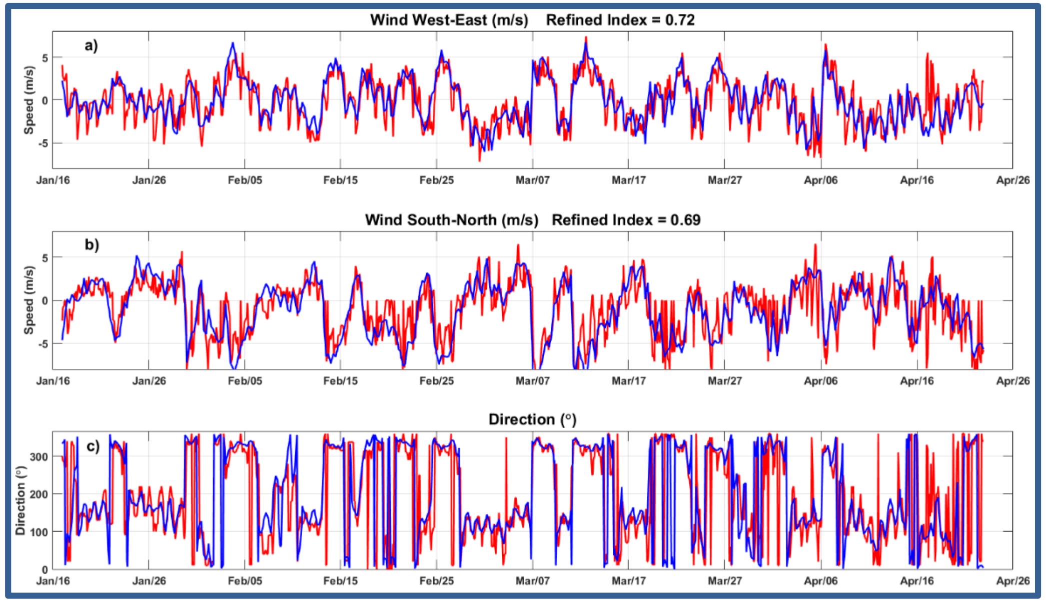
Doha International Airport weather station

- 25.33°, 51.52° (Lat/Lon)
- <u>Wind Speed</u> (m/s) / <u>Direction</u> (°)
- Jan, 17th to Apr, 22nd , 2013
- Elevation: 10 m

MODELING SYSTEM Model Validation





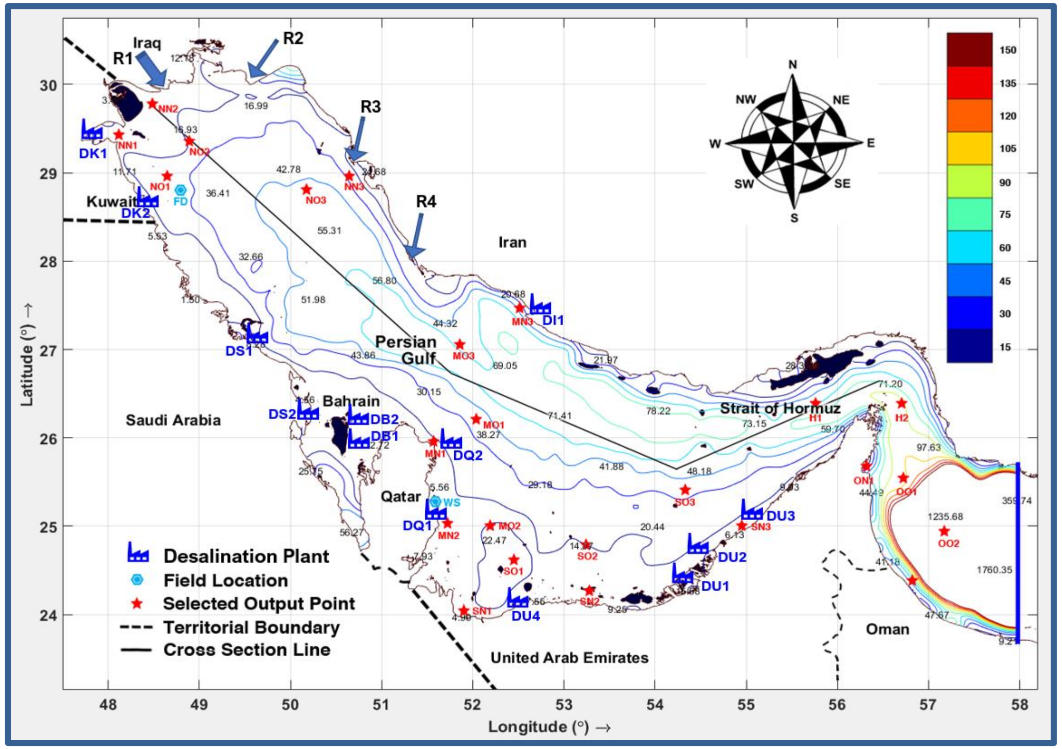


Refined Index of Agreement (Wilmott et al. 2012)

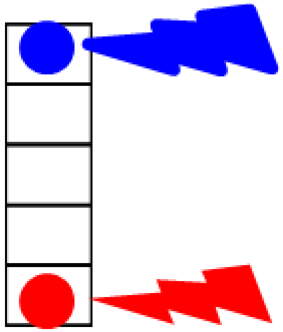
$$d_r = 1 - \frac{\sum_{i=1}^{n}|P_i - \bar{O}| + |O_i - \bar{O}|}{\sum_{i=1}^{n}(|O_i - \bar{O}| + |O_i - \bar{O}|)} = 1 - \frac{\sum_{i=1}^{n}|P_i - O_i|}{2 \times \sum_{i=1}^{n}|O_i - \bar{O}|}$$

	Temperature at bottom	Current Speed (Bottom Layer)		Current Speed (Middle Layer)		Wind Speed	
		U	V	U	V	U	V
R.I	0.81	0.50	0.70	0.52	0.67	0.72	0.69

MODELING SYSTEM Desalination Process



Incorporate Physical Process of Desalination, in the Modeling



Source and Sink *f*(time)

flow rate (m^3/s)
salinity (ppt)
temperature (°C)

Investigate Desalination Data Elhakeem (2015)

Parameterize Desalination Process

1. Same point of in-out discharge
   : Due to the grid resolution

2. Operating continuously during the simulation time period
   : Unclear when the plants open and close the water gate at in-out discharge points

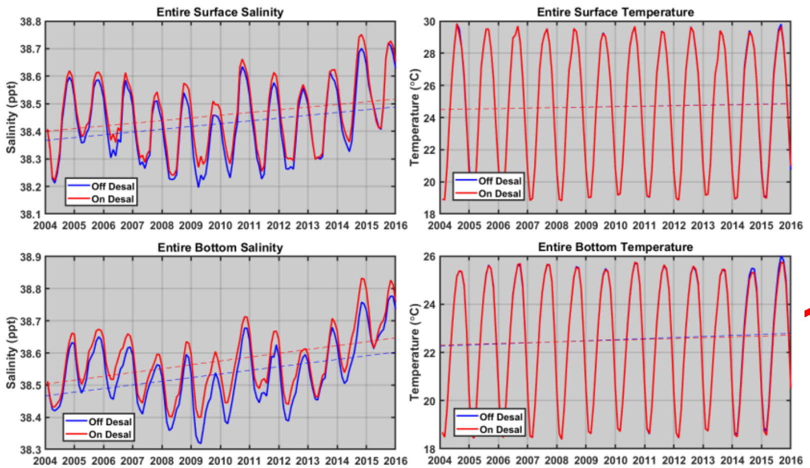
3. Difficult to define the ambient water conditions at intake points
   : Outfall discharge is specified by the relationship

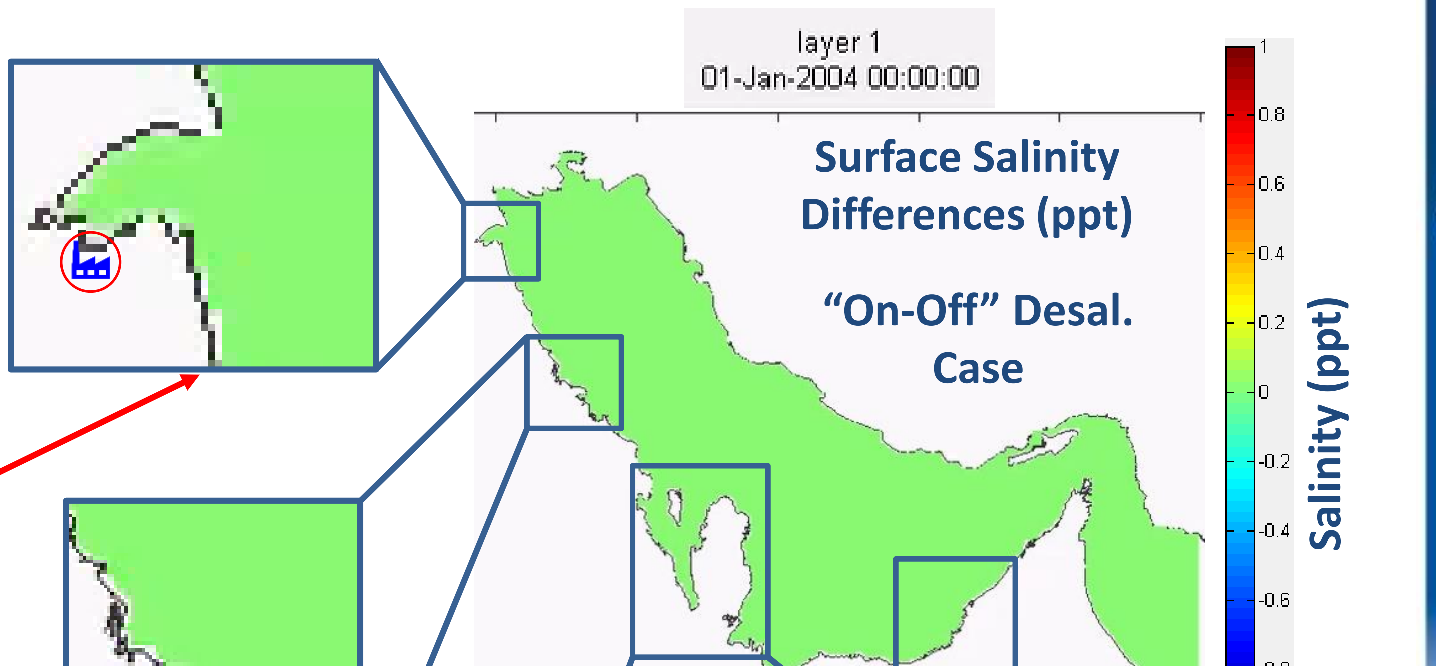
Type	Δ Salinity(ppt)	Δ Temperature (°C)
MSF	10	10
MED	15	10
RO	44.8	1

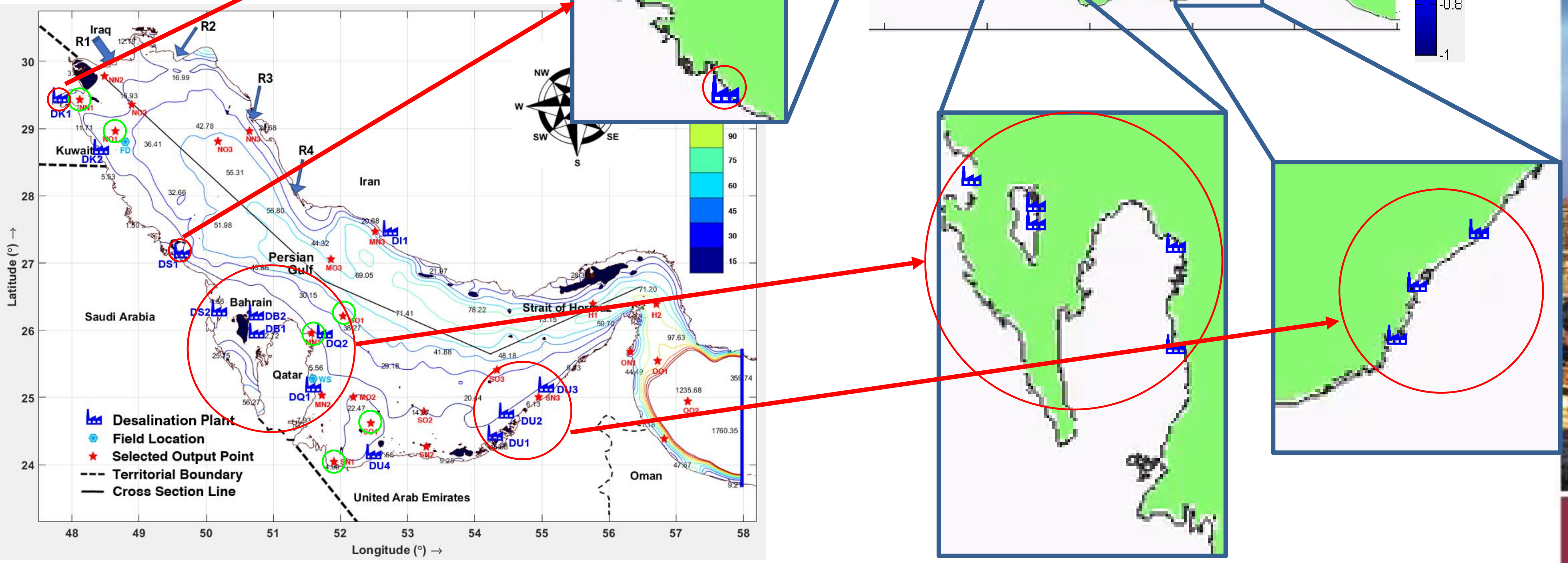
   month-by-month model runs → approx. estimation of monthly mean intake / re-simulate the model

4. According to the tendencies (Bleninger et al., 2010)
   MSF/MED with positive buoyant plume
   RO with negative buoyant plume

MODEL RESULTS







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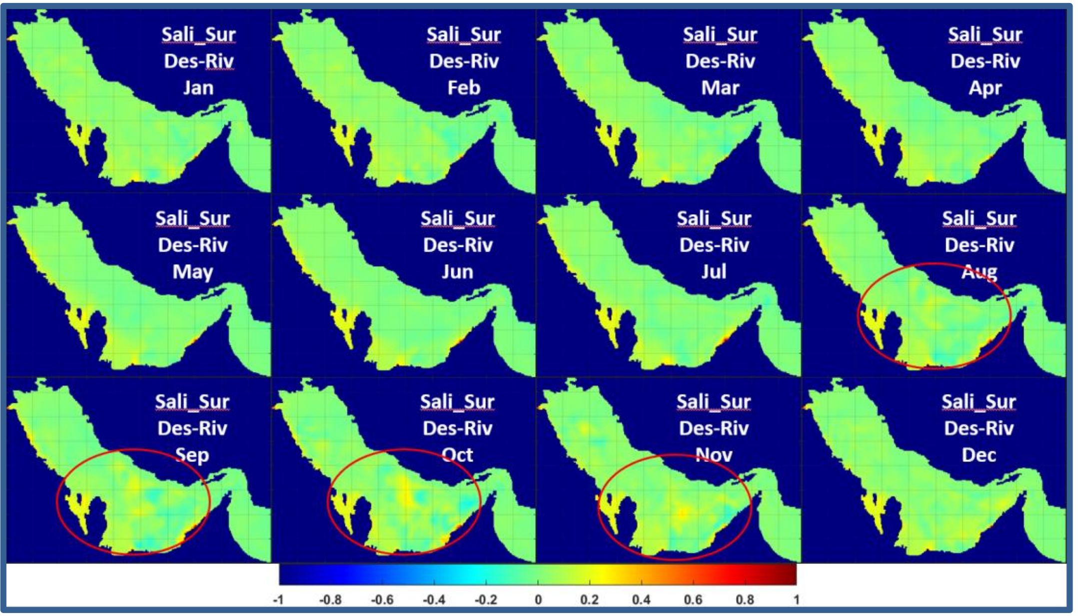

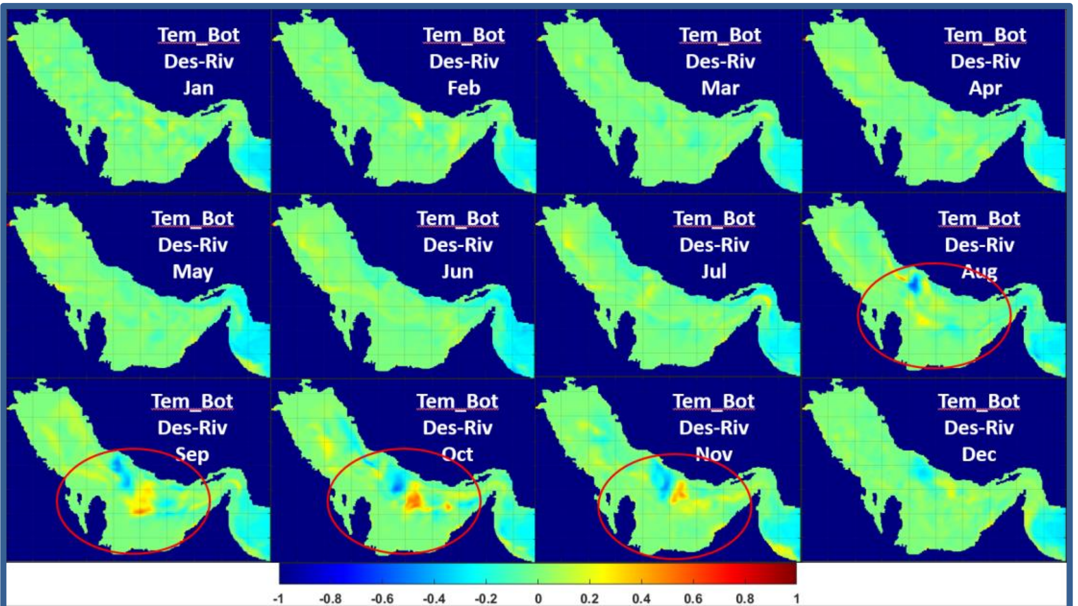

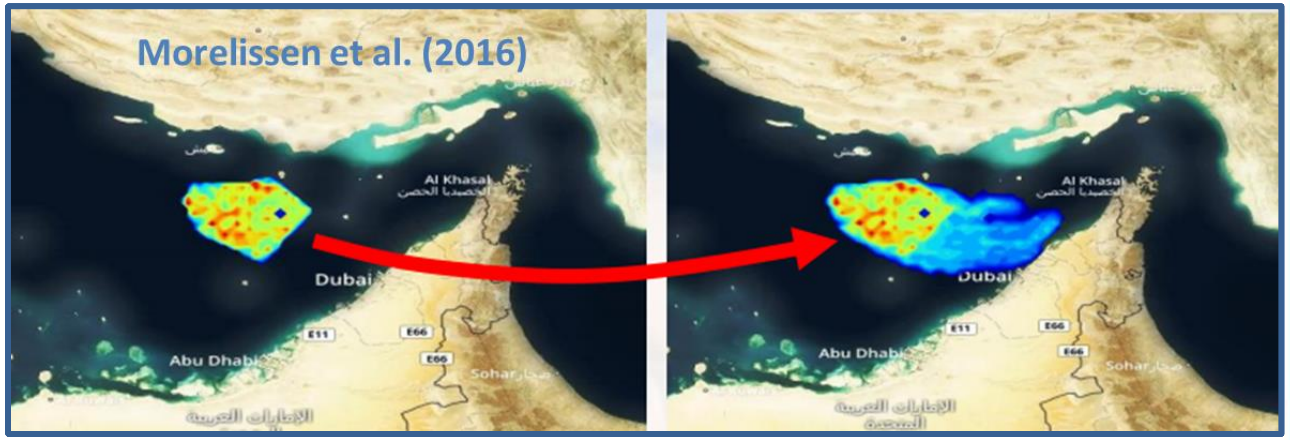

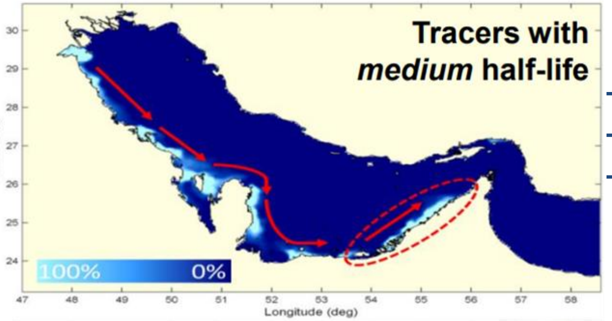

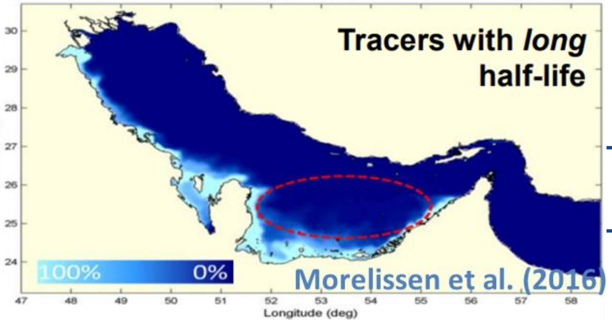

High increase in Red Circle
Why?

→ No discharge pipes of desalination plants
→ Likely due to the various physical process…
→ In similar line with the finding of Morelissen et al. (2016)
: Depictions of the Gulf circulation, pollutant tracer, spreading of harmful algae blooms, oil spills
: Tracer residence time is high in the vicinity around the red circle
→ due to Gulf circulation, evaporation, thermohaline process, IOSW inflows
→ No specific time, but…
High rate of evaporation in summer and fall lead to increased salinity and temperature

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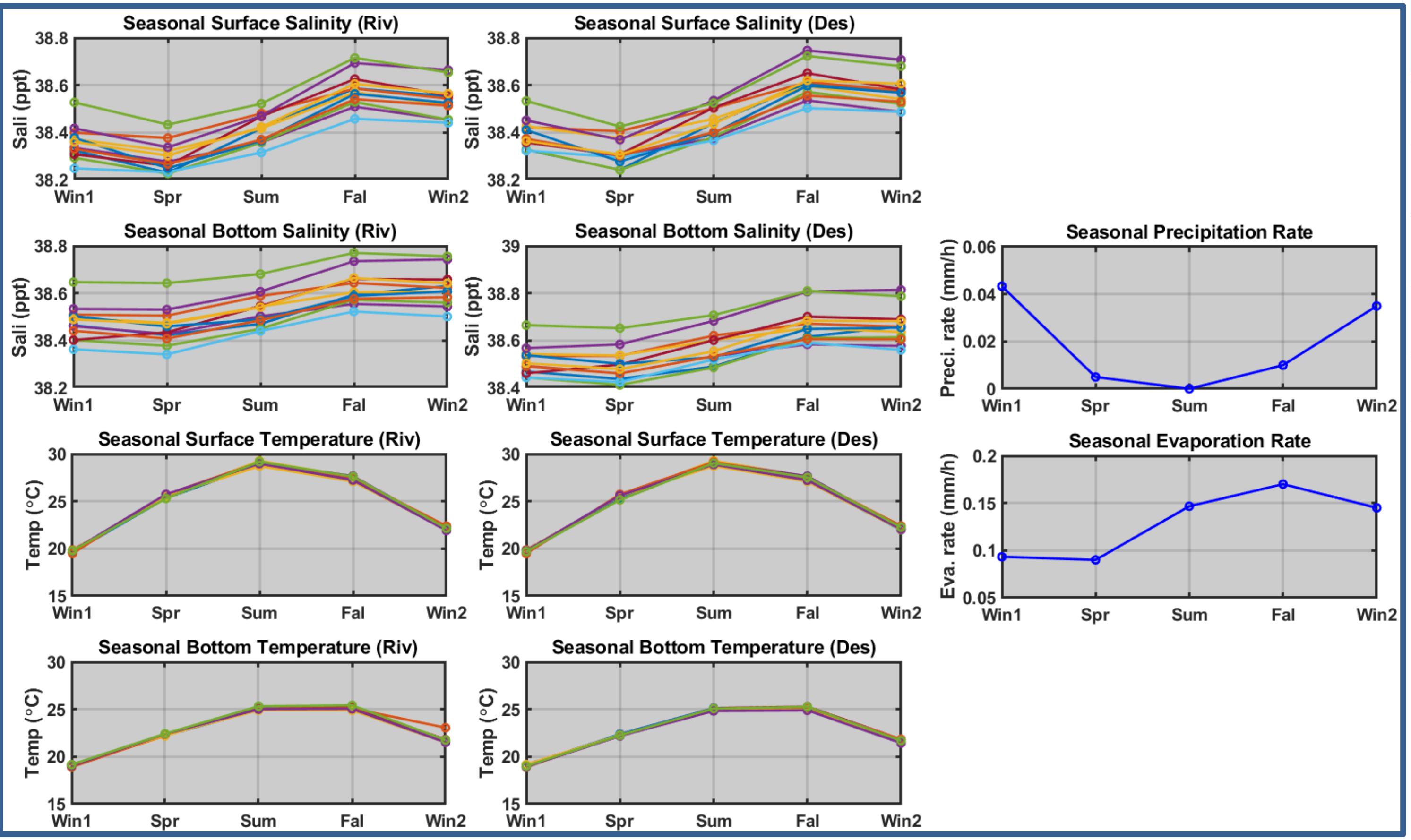
MODEL RESULTS

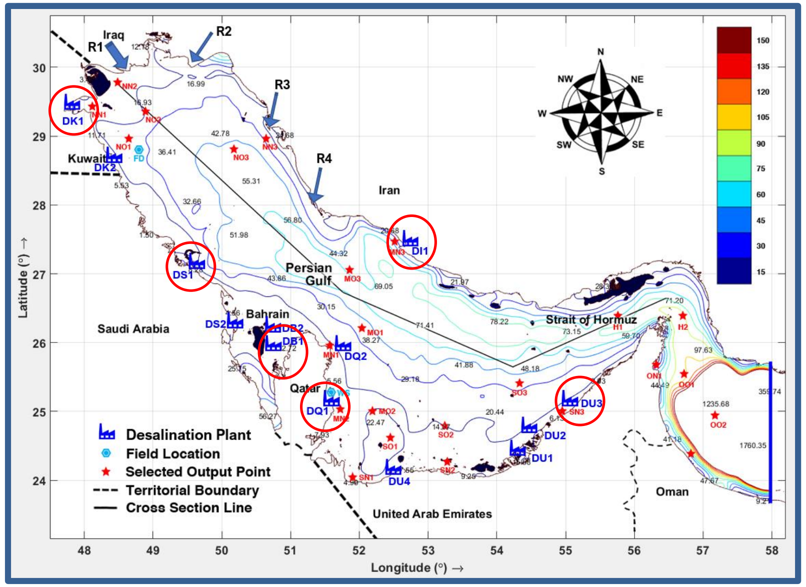


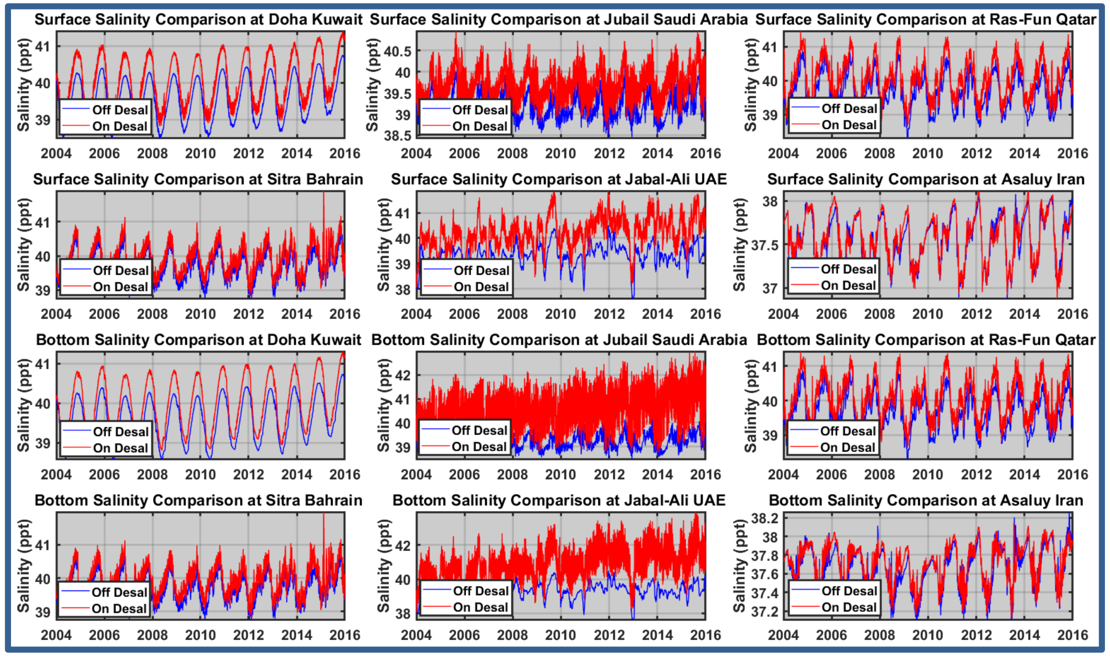
	Eva. Flux (W/m²)	Eva. Rate (m/yr)
Winter	133.15	1.68
Spring	156.62	1.98
Summer	203.92	2.57
Fall	191.14	2.41
Mean	163.60	2.06

Annual mean evaporation

1.44 m/yr (Privett, 1959)
1.8 m/yr (Kä mpf and Sadrinasab, 2006)
2.0 m/yr (Hastenrath and Lamb, 1979)
(Meshal and Hassan, 1986)
2.09 m/yr (Elhakeem et al., 2015)

MODEL RESULTS





	Country	Plant (Location)	Max. ΔSalinity	Max. ΔTemperature
1	Kuwait	Al-Doha (DK1)	0.84 ppt (Surface)	2.74 °C (Bottom)
2	Saudi Arabia	Jubail (DS1)	3.41 ppt (Bottom)	1.94 °C (Bottom)
3	Qatar	Ras Funats (DQ1)	1.16 ppt (Surface)	0.86 °C (Bottom)
4	Bahrain	Sitra (DB1)	0.88 ppt (Bottom)	0.48 °C (Bottom)
5	UAE	JabalAli (DU3)	4.21 ppt (Bottom)	1.60 °C (Surface)
6	Iran	Asaluy (DI1)	0.43 ppt (Bottom)	4.32 °C (Bottom)

Negative impacts in marine ecology

+ Growth, egg production

Dana and Lenz, 1986/Burchett et al. 1989

Brown, 1997/Boeuf and Payan, 2001

Purnama et al. 2005 / Dupavillon and Gillander 2009

+ Salinity and temperature increase

Mangroves: Salinity → sensitive to salinity change (high risk on survival)

Corals: Temperature → sensitive to temperature change (deadly impact)

Fish: potential high risk of growth and eggs production

Mollusks (like cuttlefish)

→ size and weight by 3 ppt increase

→ survival by 6 ppt increase

SUMMARY AND FUTURE DIRECTIONS

1. Provide a dependable solution "Fresh water", but…

- Arabian/Persian Gulf → Biggest user, Gulf climate, future availability of surface and groundwater
- Environmental concerns from high saline effluence from desalination
- Need to engage in long-term planning and management/ evaluate the environmental effects

2. Develop the Desalination Process in Modeling System

- Use the Delft3D-FLOW / Model runs "OFF-Desalination" and "On-Desalination"
- Parameterization of in-out desalination water cycle in modeling system
- A total of 76 desalination plants → along the Gulf coast in modeling system

3. Evaluate the Environmental Effects

- Important perspective how the effluent affects the Gulf environment. (1-2 ppt, 1-3°C increase)
- Total 76 desalination plants → salinity ↑(global gulf), temperature (locally, 0.2-1.0°C ↑)
- Seasonal characteristics → evaporation and precipitation (Highest level of salinity in Fall)
- Potential threat on the marine environment and ecosystem (Max. 4.21 ppt, 4.32°C increase)
- Provide a "worst case" scenario

4. Future Desalination

- High reliance on desalination in the Gulf → Update desalination information
- Need a near field model to simulate the dilution and mixing problems
- Incorporate effect of climate change, updated diffusion mechanism, and future desalination process

ACKNOWLEDGEMENTS

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Thank You for Attention

Questions or Comments