Modeling Salinity Changes in the Persian Gulf

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Introduction and Motivation

- The Persian Gulf is a large semi-enclosed body of water (inverted estuary)
  - Approximately 1000 km in length, 550 km in width and 240,000 km² surface area
  - in Western Asia
  - Connected through the Strait of Hormuz to the Arabian Sea and Indian Ocean.

- Increase in their standard of living in countries.
  - Kuwait, Saudi Arabia, Bahrain, Oman and United Arab Emirates.
  - Petroleum and Energy industries.
  - Expansion of desalination plants.

- Water demand is rising due to population growth and rapid development.
  - The ground water resource is diminishing with time.
  - Numerous desalination processes in Gulf are presently the major source of fresh water for all applications.

- The effects of resulting hypersaline discharges, along with shalang winds are considered.

- Distribution of seasonal salinity and its variations due to the effect of the shalang, is investigated using the Delft3D-FLOW hydrodynamic model.

Objectives

- Using the hydrodynamic model to simulate current, salinity and temperature distributions over the last decade in Persian Gulf.

- Obtain the salinity variations in Gulf. Investigate the seasonal salinity variation due to the shalang effect.

- Investigate the effect of desalination due to salinity changes of ambient conditions from the discharges of desalination plants in Persian Gulf.

- Forecast the future salinity trends for each GCC country nearshore and offshore.

Model Set up

- Initial Condition
  - Astronomical Tidal Condition.
  - Global Grid with 10 layers (5, 5, 10, 10, 20, 20, 10, 10, 5, 50 km).
- Boundary Condition
  - Initial with major river input & salinity (24 C in 0.8 yr), meteorological
  - Water Level: Contour of Astronomical Tidal Condition.
- Transport Condition: Temperature and Salinity from MyOcean Model-GLOBAL_REANALYSES_PHYS_001_2011

Results around GCC

- Wind Drag coeff. = 0.00063 – Manning Bottom roughness = 0.01
- Horizontal eddy viscosity and diffusivity = 15 m²/s
- Water and air density = 1026 kg/m³ and 1 kg/m³
- Dalton and Stanton number = 0.001 – Secchi depth = 2 m
- Wind: Space varying wind and Pressure (Climate Forecast System Reanalyses data – http://cfs.ncep.noaa.gov)

Simulation Results

Seasonal Variation

- Desalination effect: Comparison of salinity distribution in 2009 (April) and 2012 (April).
- Other effects: Comparison of current and salinity distribution in 2012 (April)

Other Effects

- Desalination plants: 75 energy and desalination plants
- Water demand: rising due to population growth and rapid development.
- Inflows and outflows: strongly dynamic throughout the Strait of Hormuz.

Future Plans

- Transport boundary condition: Decrease trends of salinity in this study.
- Need further model validation and new source of desalination in Gulf.
- Developments in modeling to forecast the future salinity trends in Persian Gulf.

Seasonal Variation

Summary of Results

- Salinity changes surrounding Kuwait, KSA, Bahrain, Qatar, Oman and UAE:
- Comparison salinity changes between two cases with and without desalination discharges surrounding Qatar and UAE.
- Due to increasing fresh water demands today, numerous desalination plants have been built in Gulf. The salinity has apparently increased since 2011.
- Desalination led to higher salinity near the coastal area close to desalination plants, so that it can be environmental impacts in water circulation of Gulf.
- Seasonal variations of salinity.

- Surrouding Kuwait and KSA, the minimum salinity shows in April – July, and maximum salinity attains in October – January.
- Effect of rivers run-off and seasonal wind shalang are considered over entire Gulf scale. As inflows of low-salinity and varying simulation with minimum value in October and maximum in April, it shows a good agreement with seasonal and decreased salinity changes in simulation results.
- The larger variations of salinity are shown on the surface during the summer season.
- Other effects:
  - Due to the river discharges, low-salinity is shown surrounding 4 major rivers.
  - Inflow and outflow are strongly dynamic throughout the Strait of Hormuz.

Model Validations

  - Location: 28 50.938’N, 48 47.534’E. Offshore of Kuwait (FM in Figure 1)
  - Data: Temperature and Current at the bottom layer.
- Field wind from the weather station of Doha INTL. Airport (Jan.1, ~ Dec.31, 2010)
  - Location: 25 16’1.2’’N, 51 32’60’’E (WM in Figure 1).

References:

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Other Effects

- Due to the river discharges, low-salinity is shown surrounding 4 major rivers.
- Inflow and outflow are strongly dynamic throughout the Strait of Hormuz.
- Desalination effect and seasonal characteristics are thus less evident.

Future Plans

- Need further model validation and new source of desalination in Gulf.
- Developments in modeling to forecast the future salinity trends in Persian Gulf.