Prediction of Instantaneous Currents for Naval Applications

Peter C. Chu, Kleanthis Kyriakidis, Albert Armstrong
Naval Postgraduate School

Steven D. Haeger
Naval Oceanographic Office

Matthew Ward
Applied Science Association

San Diego Bay
San Diego Bay Bathymetry
Homeland Security
Diving Operations & Special Warfare
ADCP Stations (SPAWAR 1993)
U Component from ADCP at NB1
surface (yellow), middle depth (purple) and bottom (blue)

U in water column for NB1

U (cm/s)

time (in 10 s)
V Component from ADCP at NB1

surface (yellow), middle depth (purple) and bottom (blue)
U Component from ADCP at NB2

surface (yellow), middle depth (purple) and bottom (blue)
V Component from ADCP at NB2

surface (yellow), middle depth (purple) and bottom (blue)

V in water column for NB2

V (cm/s)

time (in 10 s)
WQMAP (ASA)

- Hydrostatic
- Forced by tides
- Land boundaries assumed impermeable
  (normal component of velocity set to zero).
- At closed boundaries transport of substance
  (i.e. salinity) is zero.
- At open boundaries, concentration specified
  during the inflow, using characteristic values.
Hydrodynamic Model
WQMAP (ASA)

Momentum Equation in $\xi$-direction

\[
\frac{\partial UD}{\partial t} + \frac{1}{\sqrt{g_{11}g_{22}}} \left[ \frac{\partial \left( U^2 D \sqrt{g_{22}} \right)}{\partial \xi} + \frac{\partial \left( UVD \sqrt{g_{11}} \right)}{\partial \eta} + UVD \frac{\partial \left( \sqrt{g_{11}} \right)}{\partial \eta} - V^2 \frac{\partial \left( \sqrt{g_{22}} \right)}{\partial \xi} \right] - fDV
\]

\[
= - \frac{gD}{R \sqrt{g_{11}}} \left[ \frac{\partial \xi}{\partial \xi} + \frac{D}{\rho_0} \int_{-\infty}^{\infty} \left( \frac{\partial \rho}{\partial \xi} - \sigma \frac{\partial D}{\partial \xi} \frac{\partial \rho}{\partial \sigma} \right) d\sigma \right]
\]
Momentum Equation in $\eta$-direction

$$\begin{align*}
\frac{\partial V_D}{\partial t} + \frac{1}{\sqrt{g_{11}g_{22}}} \left[ \frac{\partial (UVD\sqrt{g_{22}})}{\partial \xi} + \frac{\partial (V^2D\sqrt{g_{11}})}{\partial \eta} + UVD \frac{\partial (\sqrt{g_{22}})}{\partial \xi} - U^2 \frac{\partial (\sqrt{g_{11}})}{\partial \eta} \right] + fDV \\
= -\frac{gD}{R\sqrt{g_{22}}} \left[ \frac{\partial \xi}{\partial \eta} + \frac{D}{\rho_0} \int_0^\sigma \left( \frac{\partial \rho}{\partial \eta} - \frac{\sigma}{D} \frac{\partial D}{\partial \eta} \frac{\partial \rho}{\partial \sigma} \right) d\sigma \right]
\end{align*}$$
Hydrodynamic Model
WQMAP (ASA)

\[ \text{Continuity} \]

\[ R \sqrt{g_{11}g_{22}} \frac{\partial \zeta}{\partial t} + \frac{\partial \left( UD \sqrt{g_{22}} \right)}{\partial \xi} + \frac{\partial \left( VD \sqrt{g_{11}} \right)}{\partial \eta} = 0 \]
MODEL EVALUATION/ VELOCITY COMPONENTS

Data/Model comparison:

**Mean values differences**: 0.49–1.29 cm/s

**Deviation values differences**: 0.44 – 6.70

**Correlation Coefficient**: 91.66 - 92.60%

**Root Mean Square Error**: 6.73–9.02 cm/s

**Error Coefficient Variation**: 6.8 – 16.76
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<tr>
<th>TIDE</th>
<th>FREQ</th>
<th>AMPL</th>
<th>AMP.ERR</th>
<th>PHASE</th>
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<th>SNR</th>
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<td>0.003</td>
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<td>*K1</td>
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<td>60.54</td>
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<td>J1</td>
<td>0.0432929</td>
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<td>0.002</td>
<td>97.99</td>
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<td>*OO1</td>
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<td>0.003</td>
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<td>*N2</td>
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<td>0.014</td>
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<td>7.74</td>
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<td>*M2</td>
<td>0.0805114</td>
<td>0.5804</td>
<td>0.015</td>
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<td>*S2</td>
<td>0.0833333</td>
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<td>0.011</td>
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<td>0.001</td>
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<td>15.82</td>
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<td>0.001</td>
<td>66.29</td>
<td>51.91</td>
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<td>0.0037</td>
<td>0.001</td>
<td>185.30</td>
<td>24.66</td>
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<td>2SK5</td>
<td>0.2084474</td>
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<td>0.001</td>
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<td>225.54</td>
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<td>*M6</td>
<td>0.2415342</td>
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<td>52.23</td>
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<td>0.002</td>
<td>83.37</td>
<td>75.50</td>
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<td>*3MK7</td>
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<td>108.25</td>
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<td>0.000</td>
<td>295.35</td>
<td>30.49</td>
<td>3.3</td>
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Initial Tidal Forcing
Semi-Diurnal Tides
# Model Evaluation / Elevation

## Data/Model Comparison:

<table>
<thead>
<tr>
<th></th>
<th>NOAA</th>
<th>SPAWAR</th>
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<tbody>
<tr>
<td>M2 (ampl dif)</td>
<td>+ 2.51 cm</td>
<td>+ 3.83 cm</td>
</tr>
<tr>
<td>S2 (ampl dif)</td>
<td>+ 0.71 cm</td>
<td>- 1.1 cm</td>
</tr>
<tr>
<td>M2 (ph dif)</td>
<td>+ 0.75 °</td>
<td>- 1.71 °</td>
</tr>
<tr>
<td>S2 (ph dif)</td>
<td>- 48.96 °</td>
<td>+ 5.41 °</td>
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</table>
WQMAP coupled rapid response models
CHEMMAP Overview

Chemical database:
- international references
- physical properties (solubility, volatility, floatability)

Chemical fate model:
- Lagrangian approach
- spreading, entrainment, evaporation, dispersion, dissolution, sedimentation and degradation
- vertical velocity relies on Stoke’s Law
- mass transported with wind field and WQMAP issued currents.
CHEMMAP MODEL

- Predicts trajectory/fate of floating, sinking, evaporating, soluble and insoluble chemicals and product mixtures.

- Estimates the distribution of chemical elements on the surface, in the water column and in the sediments.

- Langrangian approach
## CHEMMAP MODEL SELECTION OF CHEMICALS

<table>
<thead>
<tr>
<th></th>
<th>Methanol</th>
<th>Benzene</th>
<th>Ammonia</th>
<th>Chloro-benzene</th>
<th>TCE</th>
<th>Napthalene (gas)</th>
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<tr>
<td><strong>Floatation</strong></td>
<td>Floater</td>
<td>Floater</td>
<td>Floater</td>
<td>Sinker</td>
<td>Sinker</td>
<td>Sinker/ Air dispersed</td>
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<td><strong>Solubility</strong></td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Normal</td>
<td>High</td>
<td>Semi</td>
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<tr>
<td><strong>Volatility</strong></td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Semi</td>
<td>Semi</td>
<td>None</td>
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<tr>
<td><strong>Absorption</strong></td>
<td>Dissolves</td>
<td>Moderate</td>
<td>Slight</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
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<tr>
<td><strong>Flammability</strong></td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td></td>
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<tr>
<td><strong>Water/Air rapid interaction</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
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</tbody>
</table>
CHEMICAL THREAT SCENARIOS

12 scenarios (6 chemicals in North and South San Diego Bay)

- Methanol (1 barrel released in depth 1m).
- Benzene (10 tons in depth 1m).
- Ammonia (200 tons in depth 3m).
- Chlorobenzene (200 tons in depth 3m).
- Trichloroethylene (200 tons in depth 3m).
- Naphthalene (200 tons in depth 3m).
Chemical Release at North and South San Diego Bay

- North (location 2)
- South (location 4)
- Chemical release at 1 m depth
CHEMICAL THREAT
SCENARIOS/RESULTS
NORTH SAN DIEGO BAY

- 3 hours: San Diego port/city
- 10 hours: Entire North SD Bay
- 12 hours: Outside SD Bay
- 16-30 hours: Naval Station
- 5 days: Heavy impact on North Bay
- 20 Days: South Bay
- 32 Days: The entire SD Bay
Comparison of different chemicals’ results after spilling in South San Diego Bay

**CHEMICAL THREAT SCENARIOS/RESULTS SOUTH SAN DIEGO BAY**

- **12 hours:** Naval Station
- **15-17 days:** Small part of absorbed or dissolved chemical in San Diego city/port
- **After 32 days:** No effect to North San Diego Bay
CHEMICAL THREAT SCENARIOS
RESULTS FOR FLOATERS

- **Methanol**: after 3 days 45-50% in water column, after 20 days less than 5% - rest decayed.

- **Benzene**: 45% evaporates. After 2 days 30-50% in water column, after 20 days 8-18% - rest decayed.

- **Ammonia**: After 3 days 50-75% in water column, after 20 days 8-18% - rest decayed.
CHEMICAL THREAT SCENARIOS
RESULTS FOR SINKERS

- **Chlorobenzene**: After 5 days 65 - 97% in water column, after 20 days 50-90% - rest decayed.

- **Trichloroethylene**: After 5 days 60-93% in water column, after 20 days 38-71% - rest decayed.

- **Naphthalene (gas/air dispersed)**: After 5 days 33 - 78% in water column, after 20 days 12-33% - rest decayed.
Conclusions

• Accurate prediction of instant current is important

• Future Fleet Survey Team (FST) can become valuable asset to NAVO littoral current modeling:
  – Produce bathometry needed for boundary fitted grid.
  – Provide real time forcing data (elevation)
  – Provide real time validation data (ADCP)

• Two regimes of the chemical dispersion in San Diego Bay