Prediction of Instantaneous Currents for Naval Applications

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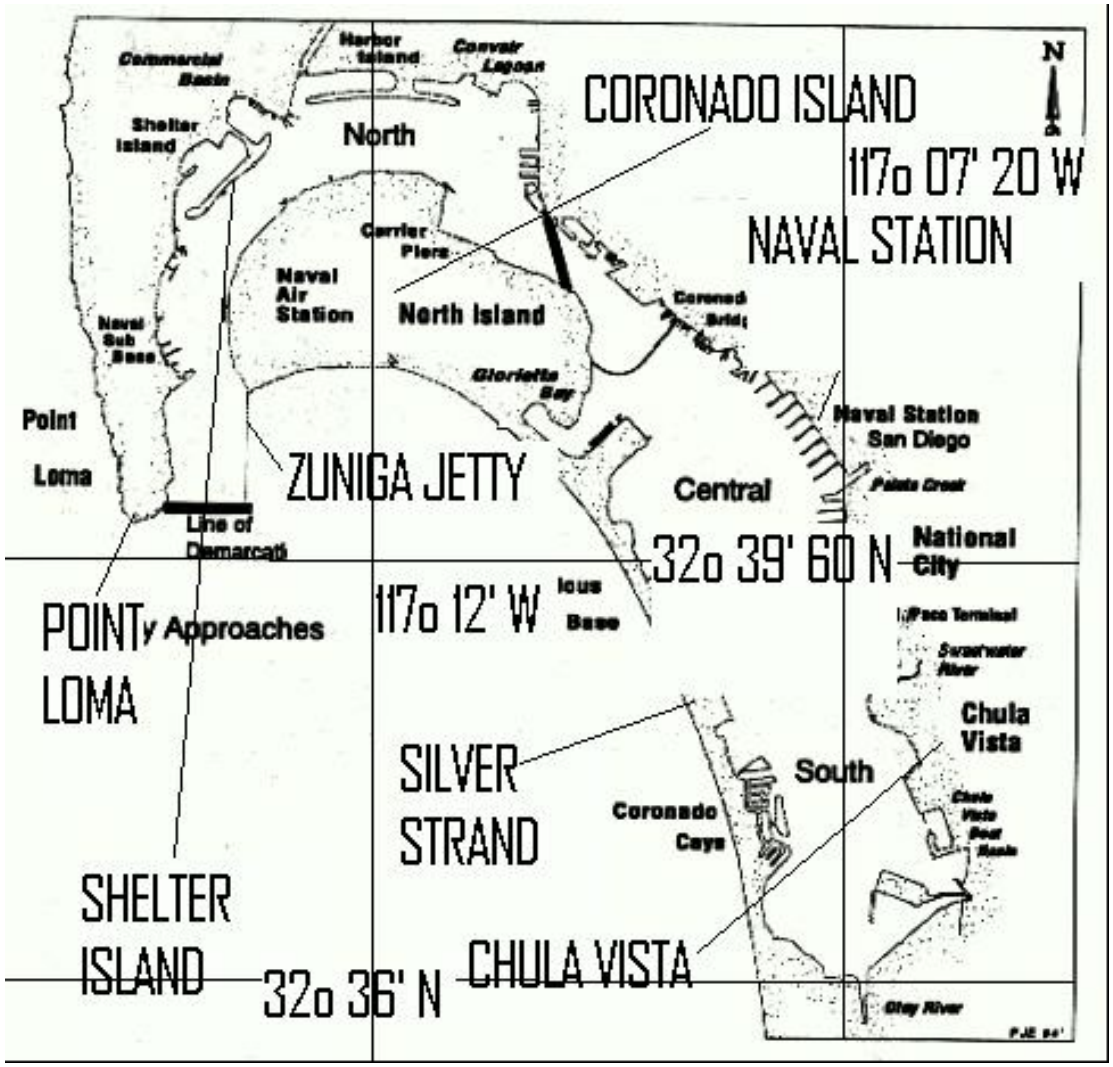
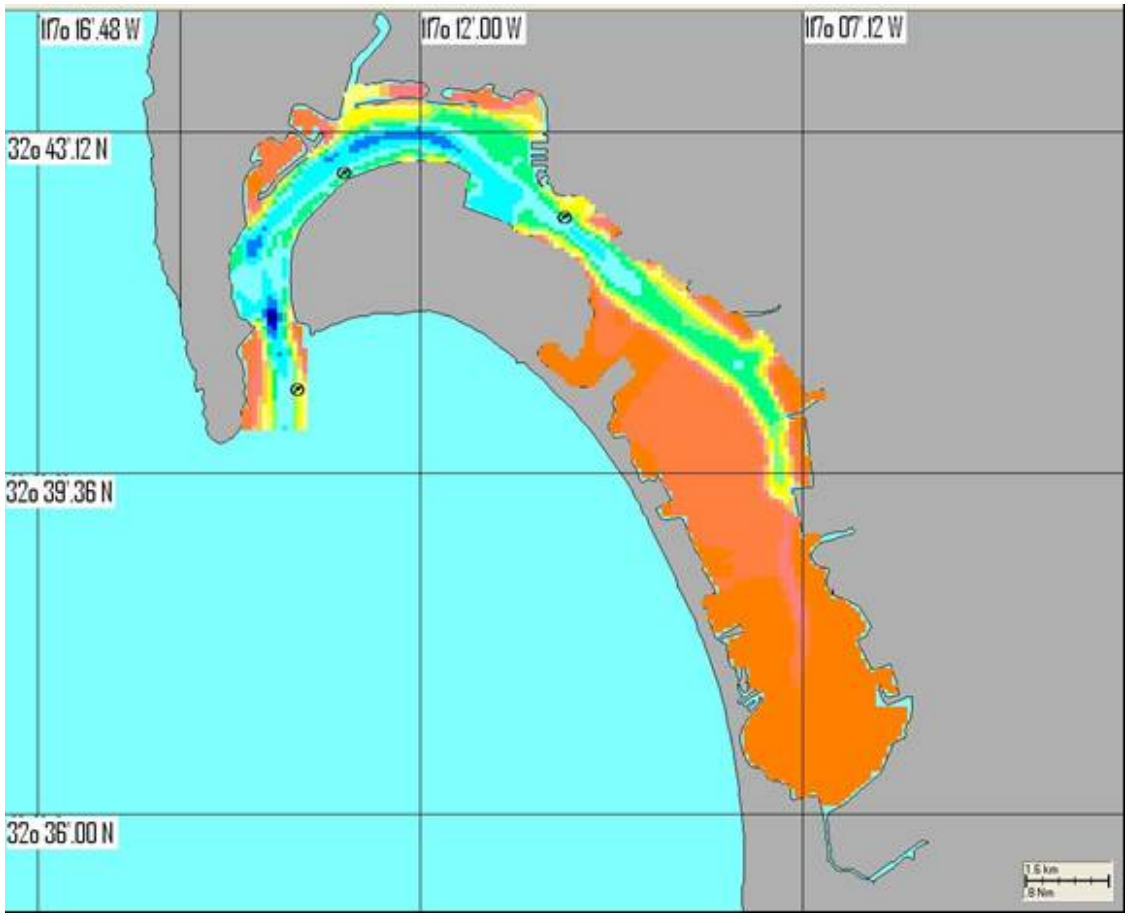
San Diego Bay



San Diego Bay Bathymetry



Depths
(meters)

- 0 -> 1.25
- 1.25 -> 2.5
- 2.5 -> 3.75
- 3.75 -> 5
- 5 -> 6.25
- 6.25 -> 7.5
- 7.5 -> 8.75
- 8.75 -> 10
- 10 -> 11.25
- 11.25 -> 12.5
- 12.5 -> 13.75
- 13.75 -> 15
- 15 -> 16.25
- 16.25 -> 17.5
- 17.5 -> 18.75
- 18.75 -> 50

Homeland Security

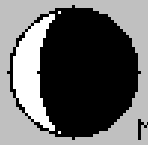
Diving Operations & Special Warfare

Current - SAN DIEGO BAY ENTRANCE

32° 40.90 N 117° 13.80 W

Harmonic station (NOAA)

Moon Phase



Moonrise: 2:58
Moonset: 16:33
Moon Phase: 319

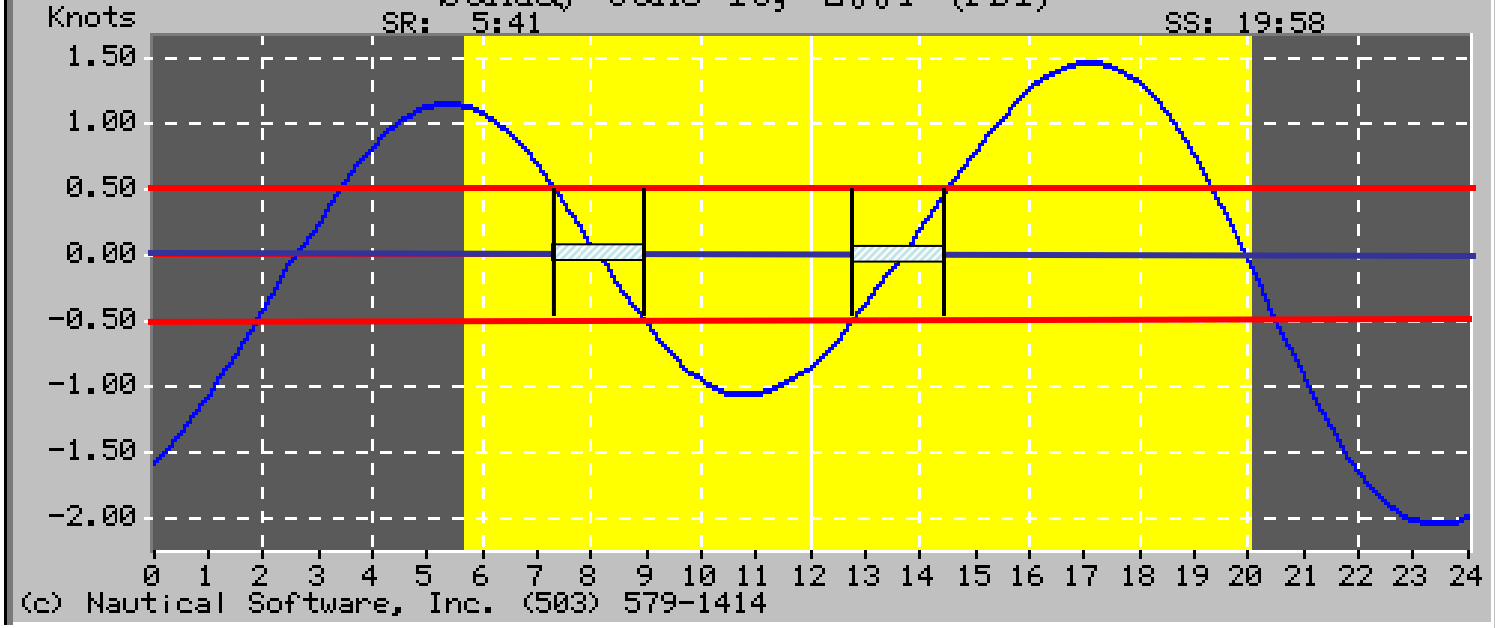
Slack Flood & Ebb

02:36	05:23	1.1kt	355°fld
08:10	10:50	-1.0kt	173°ebb
13:39	17:06	1.4kt	355°fld
19:58	23:25	-2.0kt	173°ebb

Average Currents

Min Bfr Fld:	0.0kt	- -
Max Fld:	1.2kt	355°
Min Bfr Ebb:	0.0kt	- -
Max Ebb:	1.5kt	173°

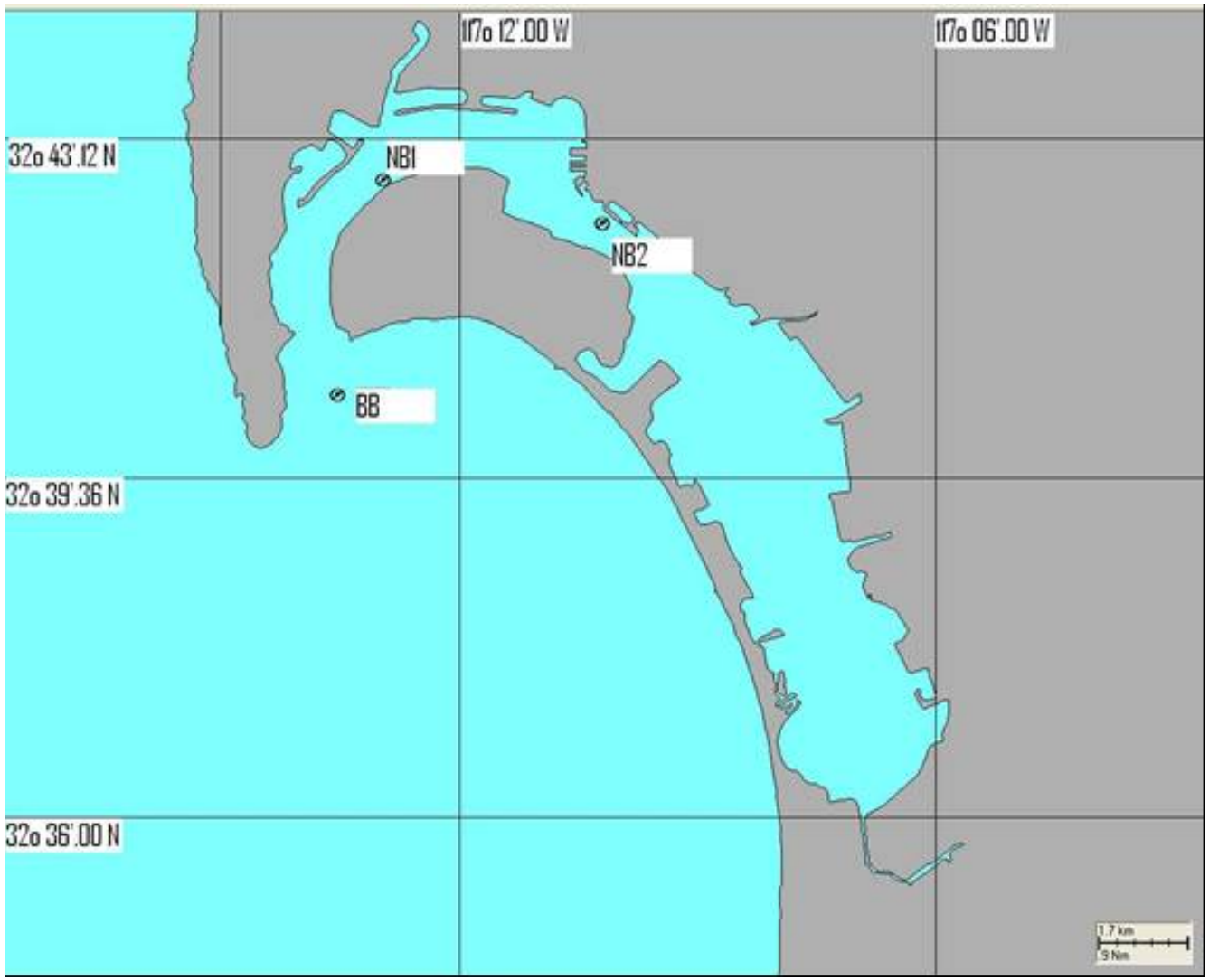
Sunday June 13, 2004 (PDT)



Current Table

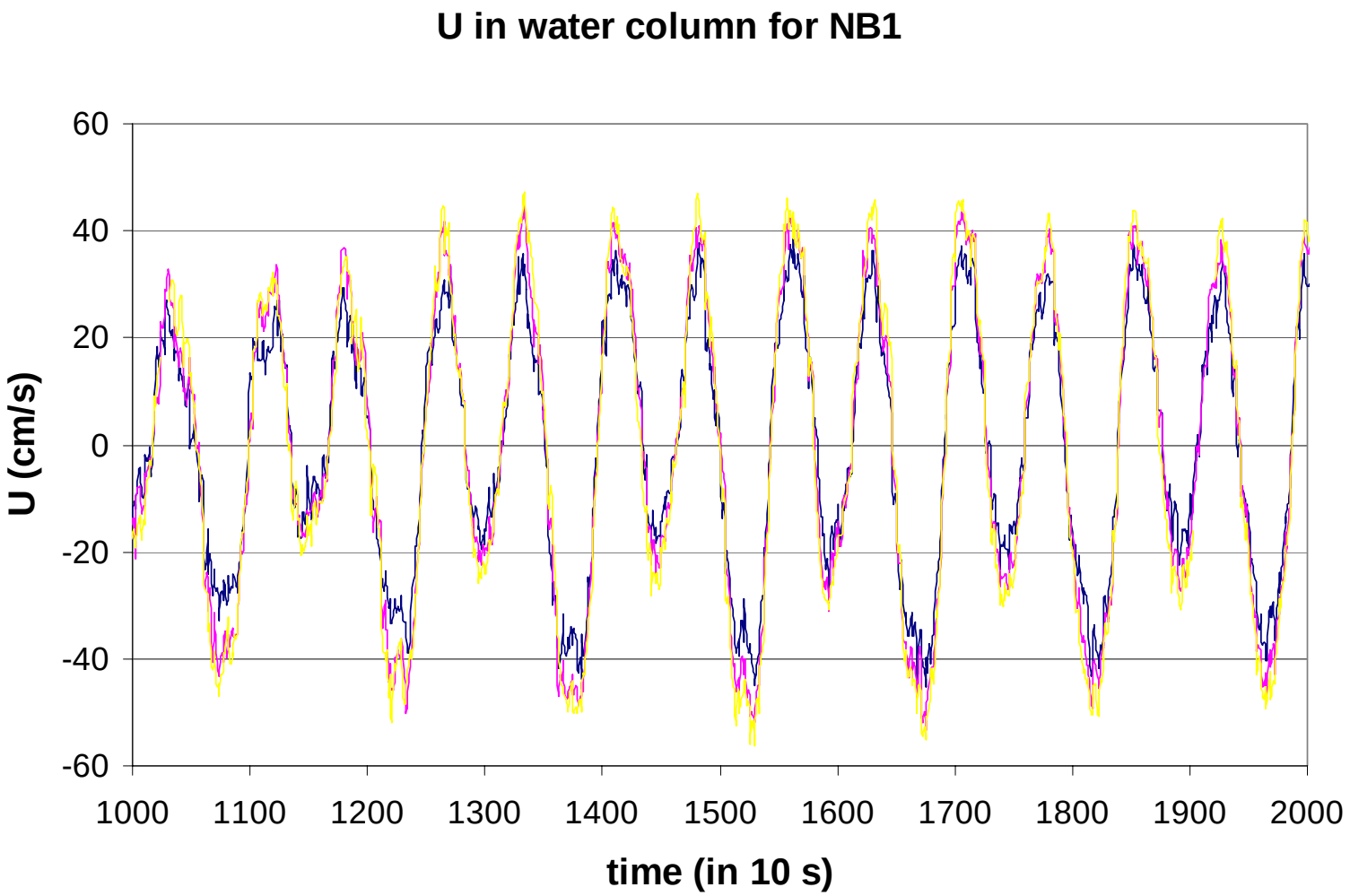
00:00	-1.5kt	E
01:00	-1.0kt	E
02:00	-0.4kt	E
03:00	0.3kt	F
04:00	0.8kt	F
05:00	1.1kt	F
06:00	1.1kt	F
07:00	0.7kt	F
08:00	0.1kt	F
09:00	-0.5kt	E
10:00	-0.9kt	E
11:00	-1.0kt	E
12:00	-0.8kt	E
13:00	-0.4kt	E
14:00	0.2kt	F
15:00	0.8kt	F
16:00	1.2kt	F
17:00	1.4kt	F
18:00	1.3kt	F
19:00	0.8kt	F
20:00	-0.0kt	S
21:00	-0.9kt	E
22:00	-1.6kt	E
23:00	-1.9kt	E
00:00	-1.9kt	E

ADCP Stations (SPAWAR 1993)



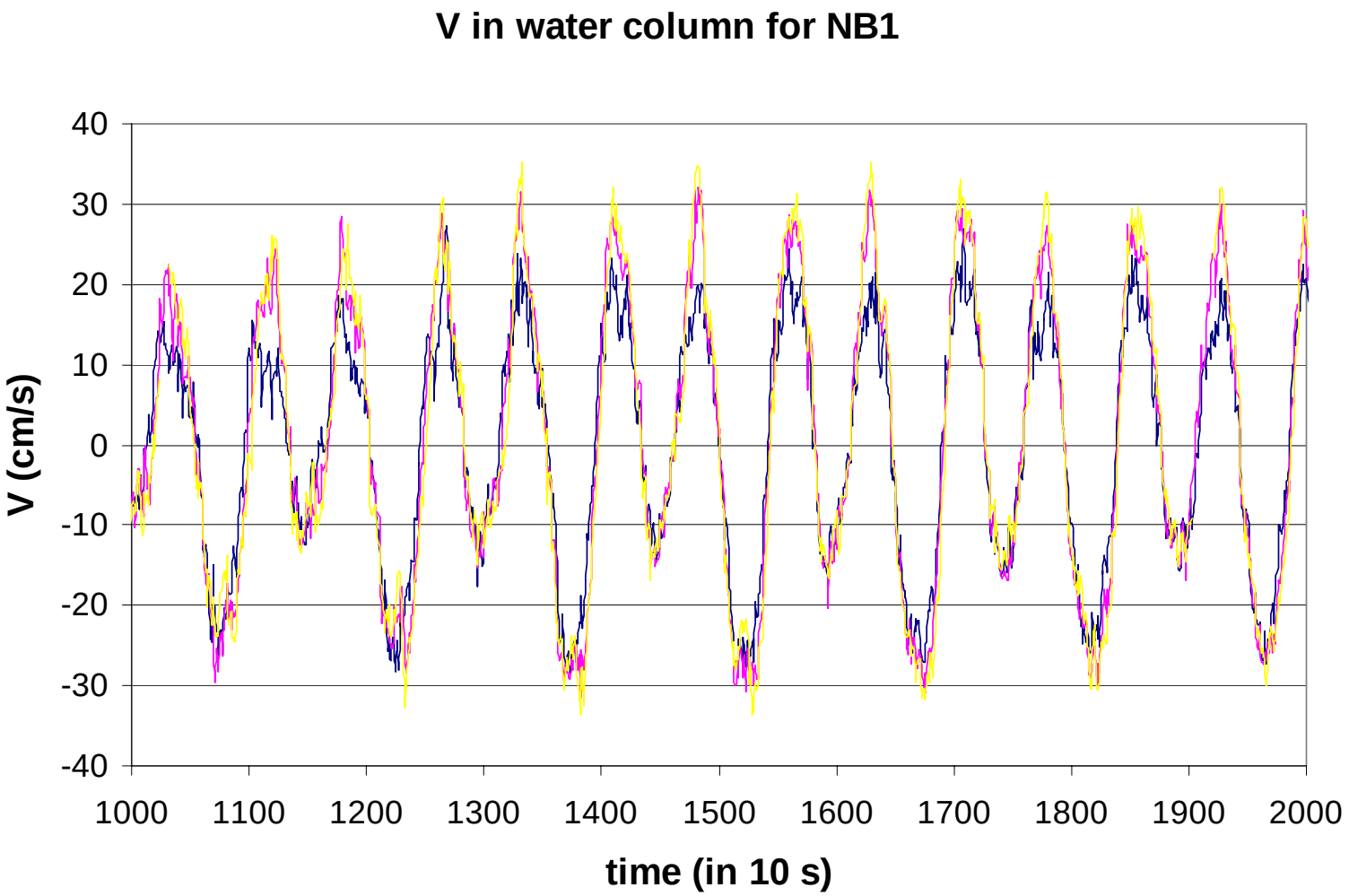
U Component from ADCP at NB1

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



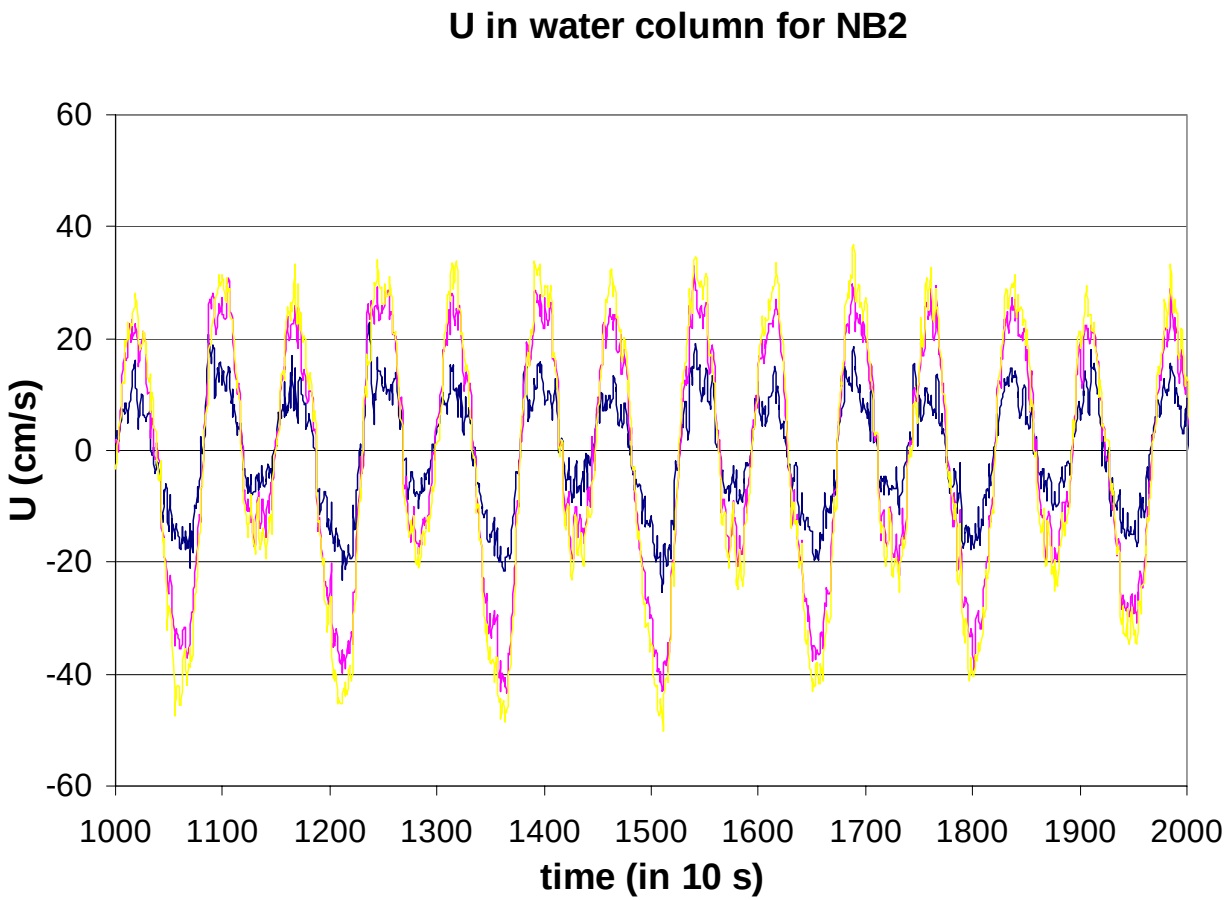
V Component from ADCP at NB1

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



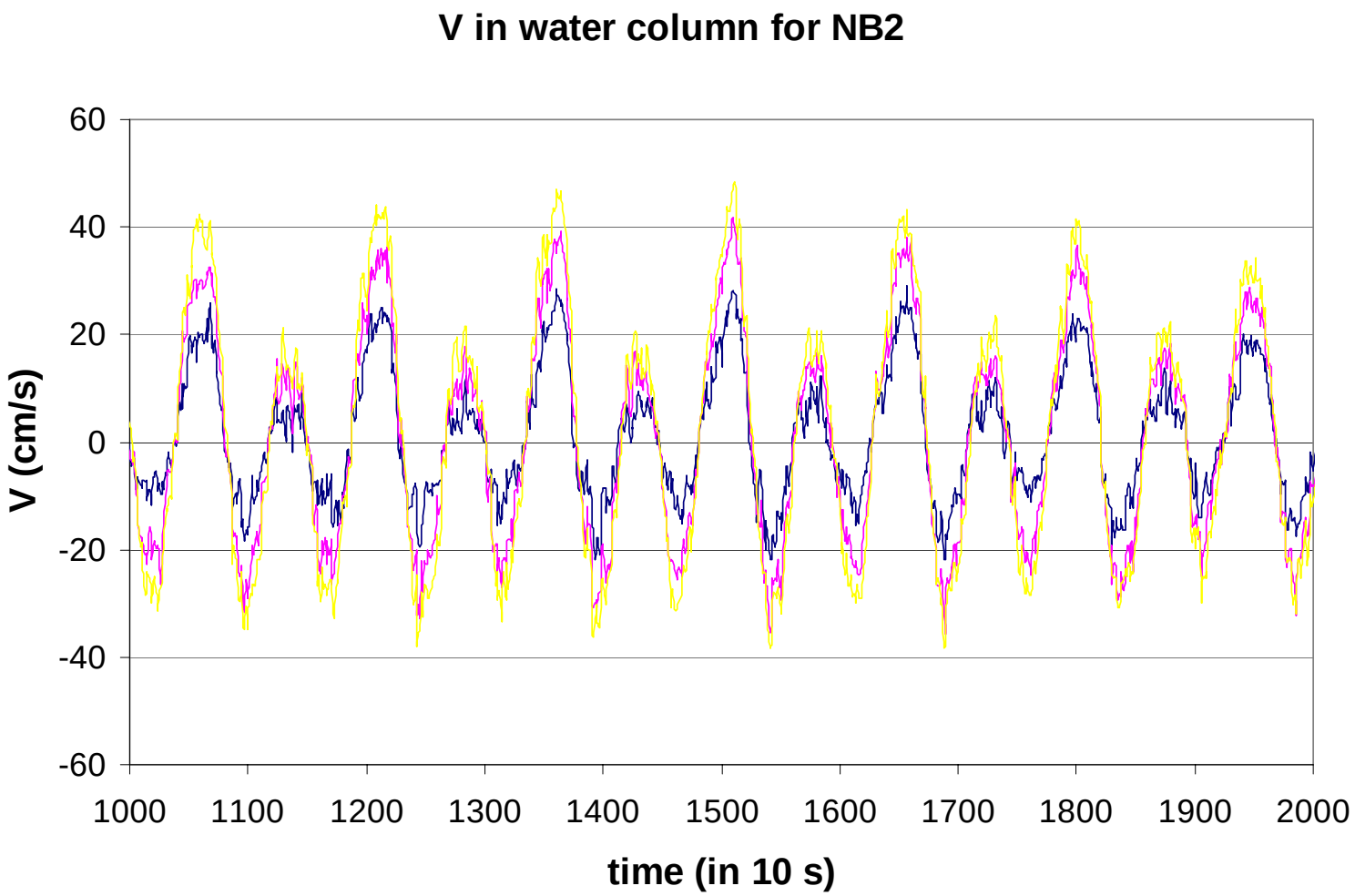
U Component from ADCP at NB2

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

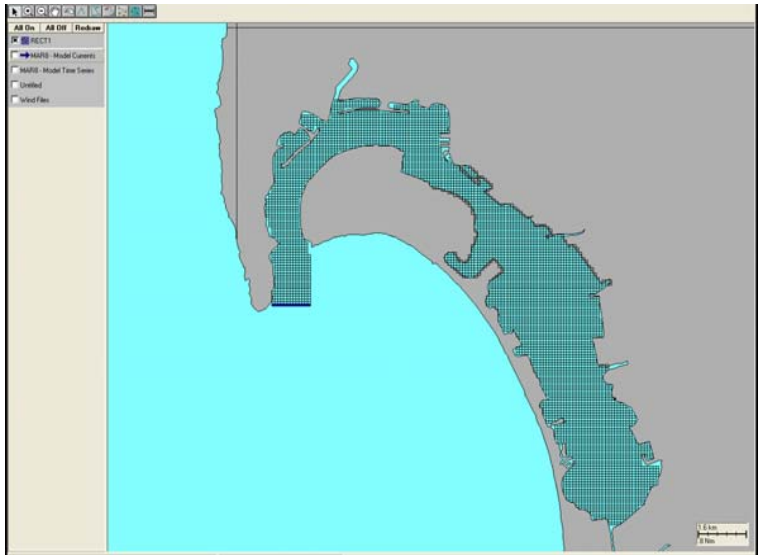


V Component from ADCP at NB2

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



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 ξ-direction

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

$$=-\frac{gD}{R\sqrt{g_{11}}}\left[\frac{\partial\zeta}{\partial\xi}+\frac{D}{\rho_0}\int_{-1}^{0}\int_{\sigma}^{0}\left(\frac{\partial\rho}{\partial\xi}-\frac{\sigma}{D}\frac{\partial D}{\partial\xi}\frac{\partial\rho}{\partial\sigma}\right)d\sigma\right]$$

Hydrodynamic Model WQMAP (ASA)

Momentum Equation in η-direction

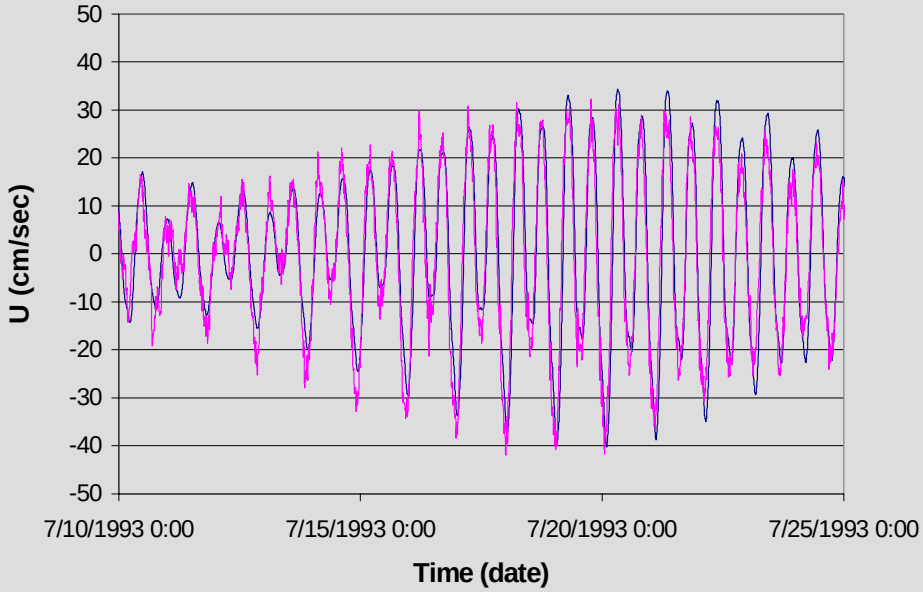
$$\frac{\partial VD}{\partial t}+\frac{1}{\sqrt{g_{11}g_{22}}}\left[\frac{\partial\left(UVD\sqrt{g_{22}}\right)}{\partial\xi}+\frac{\partial\left(V^2D\sqrt{g_{11}}\right)}{\partial\eta}+UVD\frac{\partial\left(\sqrt{g_{22}}\right)}{\partial\xi}-U^2\frac{\partial\left(\sqrt{g_{11}}\right)}{\partial\eta}\right]+fDV$$

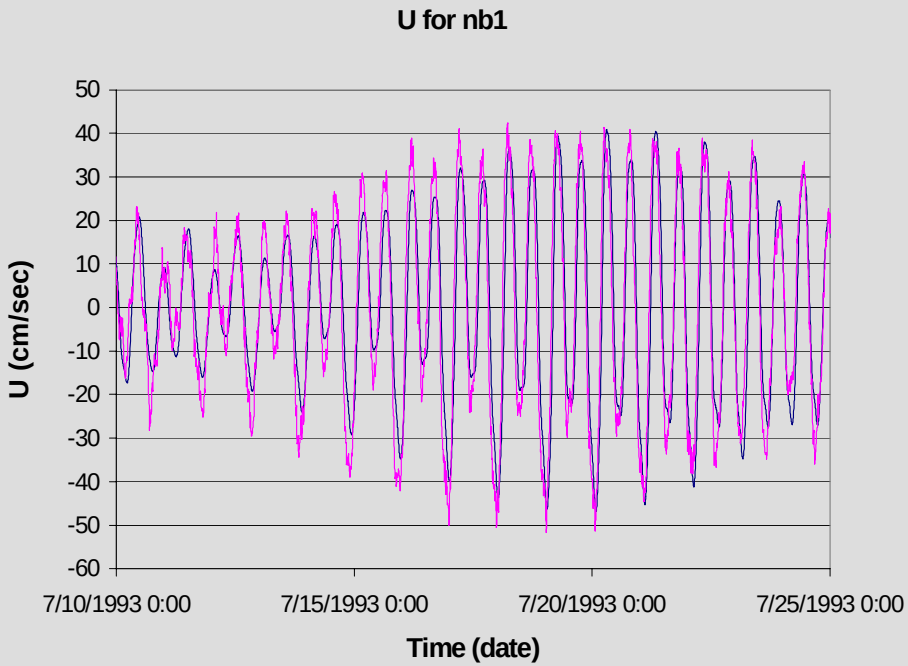
$$=-\frac{gD}{R\sqrt{g_{22}}}\left[\frac{\partial\zeta}{\partial\eta}+\frac{D}{\rho_0}\int_{-1}^{0}\int_{\sigma}^{0}\left(\frac{\partial\rho}{\partial\eta}-\frac{\sigma}{D}\frac{\partial D}{\partial\eta}\frac{\partial\rho}{\partial\sigma}\right)d\sigma\right]$$

Hydrodynamic Model WQMAP (ASA)

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%

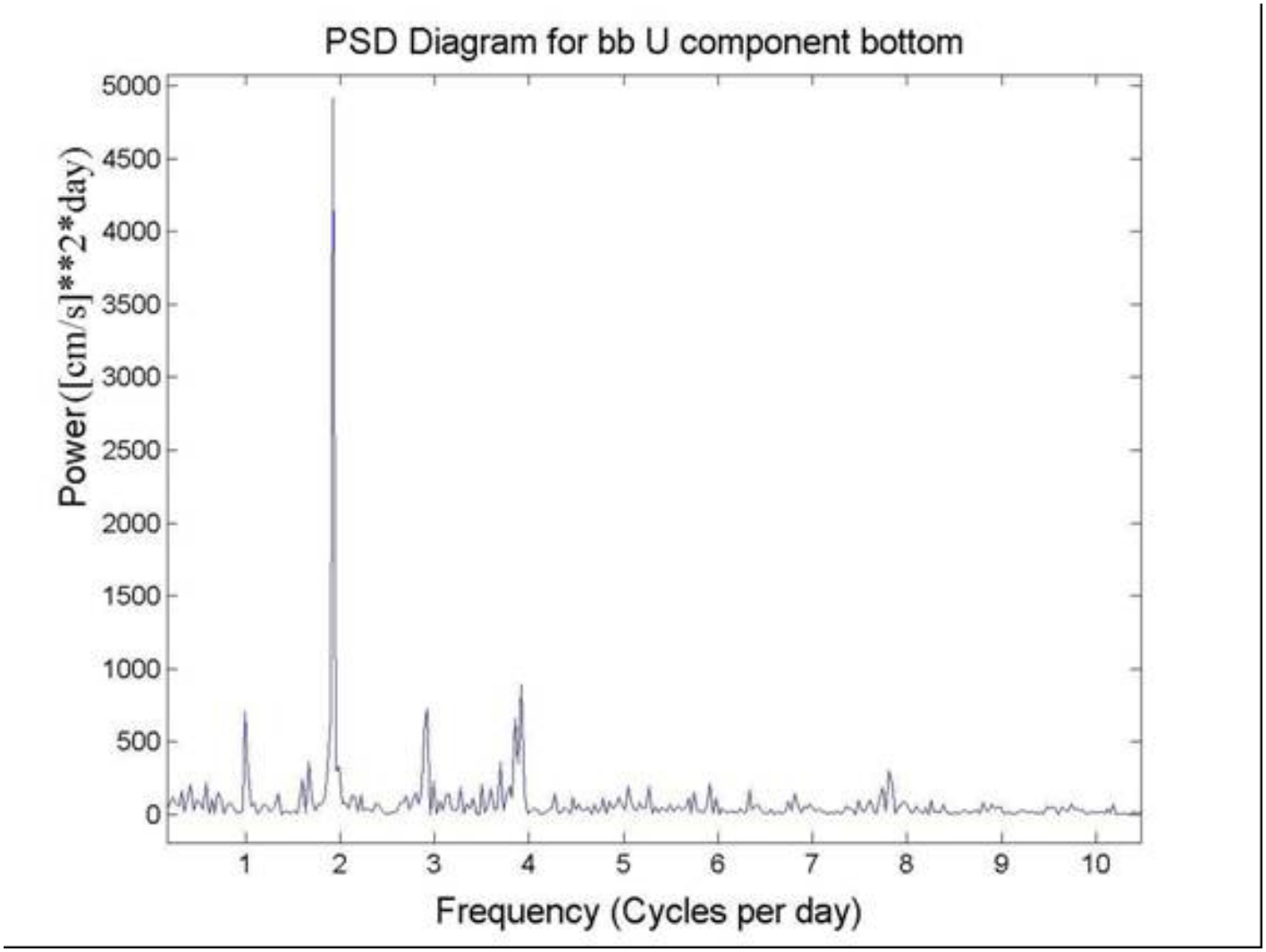
Root Mean Square Error: 6.73–9.02 cm/s

Error Coefficient Variation:6.8 – 16.76

Initial Tidal Forcing

TIDE	FREQ	AMPL	AMP.ERR	PHASE	PH ERR	SNR
MSF	0.0028219	0.0061	0.014	266.81	160.24	0.2
*2Q1	0.0357064	0.0067	0.003	337.90	21.94	6.8
*Q1	0.0372185	0.0364	0.002	76.81	4.66	2.4e+002
*O1	0.0387307	0.1952	0.003	125.14	0.86	5e+003
*NO1	0.0402686	0.0096	0.003	19.17	16.04	13
*K1	0.0417807	0.3773	0.002	60.54	0.44	2.5e+004
J1	0.0432929	0.0026	0.002	97.99	69.16	1.2
*OO1	0.0448308	0.0157	0.002	129.23	9.23	40
*UPS1	0.0463430	0.0047	0.003	289.53	32.85	2.7
*N2	0.0789992	0.1226	0.014	203.96	7.74	75
*M2	0.0805114	0.5804	0.015	270.27	1.36	1.6e+003
*S2	0.0833333	0.2144	0.013	267.04	3.93	2.6e+002
ETA2	0.0850736	0.0077	0.011	7.45	98.73	0.48
*MO3	0.1192421	0.0042	0.001	258.54	22.76	8.5
*M3	0.1207671	0.0021	0.001	172.85	40.42	2.4
*MK3	0.1222921	0.0085	0.001	219.46	10.21	33
*SK3	0.1251141	0.0026	0.001	208.56	32.29	3.7
*MN4	0.1595106	0.0039	0.002	15.82	21.09	6.1
*M4	0.1610228	0.0107	0.001	75.84	8.11	71
*MS4	0.1638447	0.0074	0.002	71.22	11.13	23
S4	0.1666667	0.0014	0.001	66.29	51.91	1.2
*2MK5	0.2028035	0.0037	0.001	185.30	24.66	6.6
2SK5	0.2084474	0.0003	0.001	258.37	225.54	0.057
2MN6	0.2400221	0.0029	0.002	355.66	52.92	1.5
*M6	0.2415342	0.0059	0.002	52.23	22.32	6.5
*2MS6	0.2443561	0.0080	0.003	72.33	18.29	10
2SM6	0.2471781	0.0019	0.002	83.37	75.50	0.65
*3MK7	0.2833149	0.0042	0.002	108.25	31.28	3.4
*M8	0.3220456	0.0007	0.000	295.35	30.49	3.3

Semi-Diurnal Tides

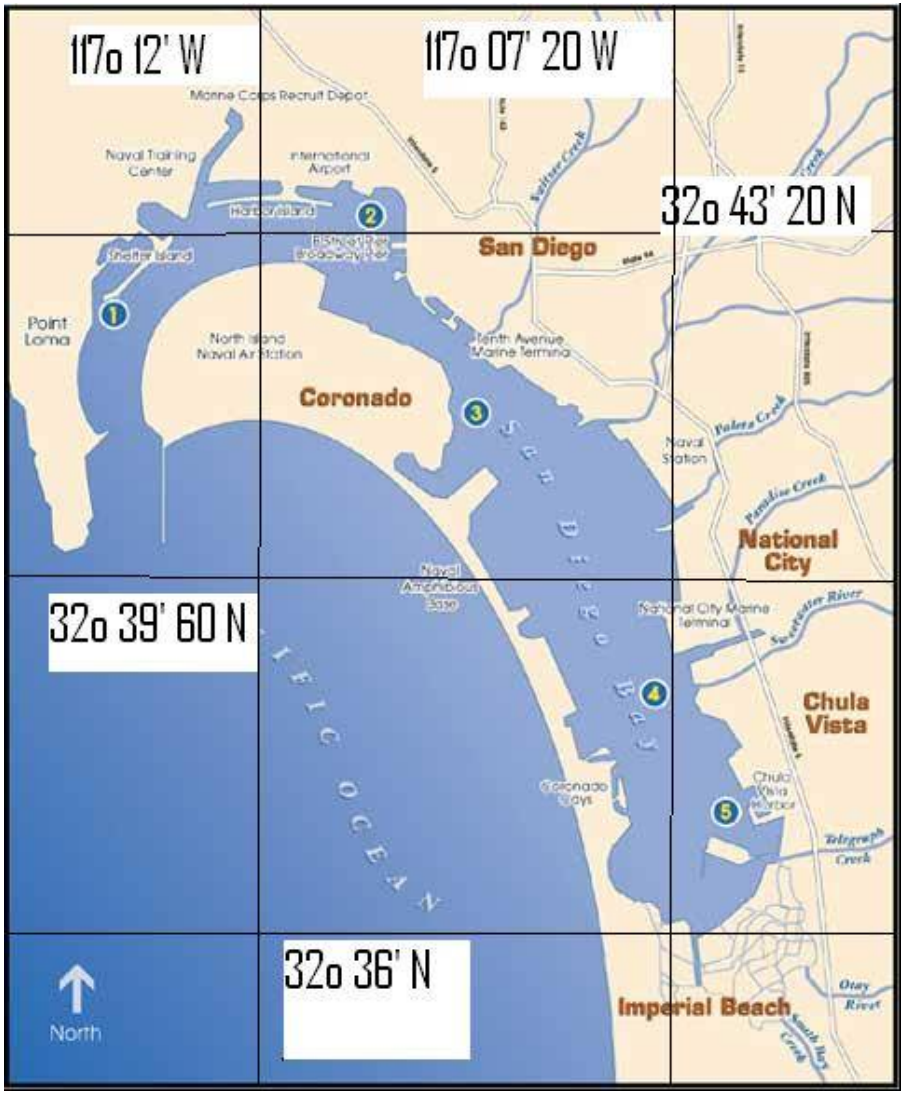


MODEL EVALUATION/ ELEVATION

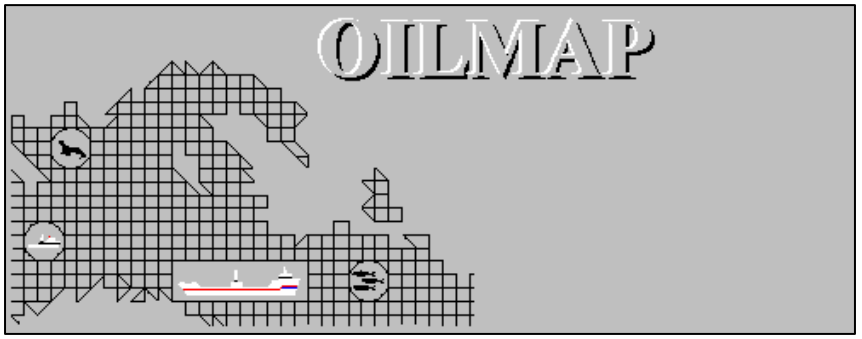
Data/Model comparison:

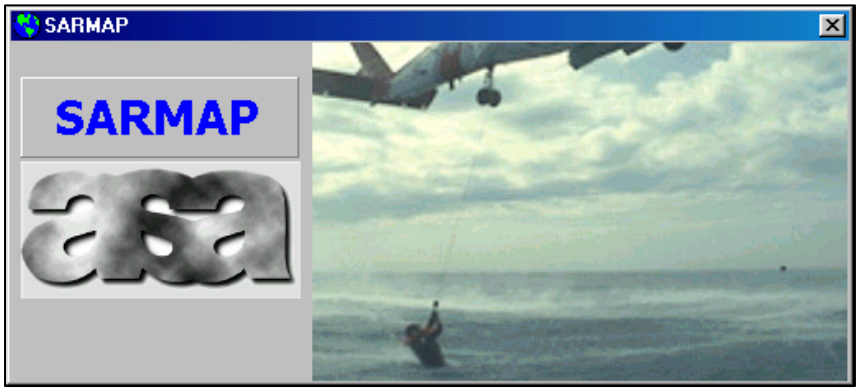
	NOAA	*SPAWAR*
M2 (ampl dif)	*+ 2.51 cm*	*+ 3.83 cm*
S2 (ampl dif)	*+ 0.71 cm*	*- 1.1 cm*
M2 (ph dif)	*+ 0.75 º*	*- 1.71 º*
S2 (ph dif)	*- 48.96 º*	*+ 5.41 º*

Water Quality Monitoring System



WQMAP coupled rapid response models





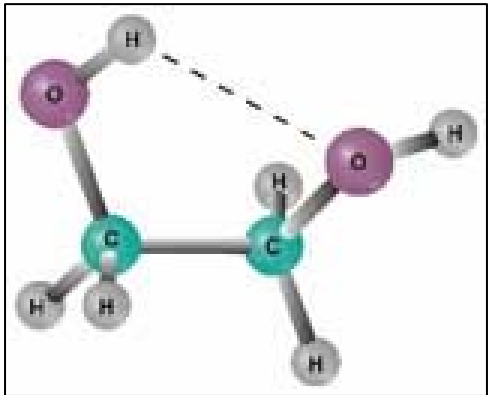
CHEMMAP Overview

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

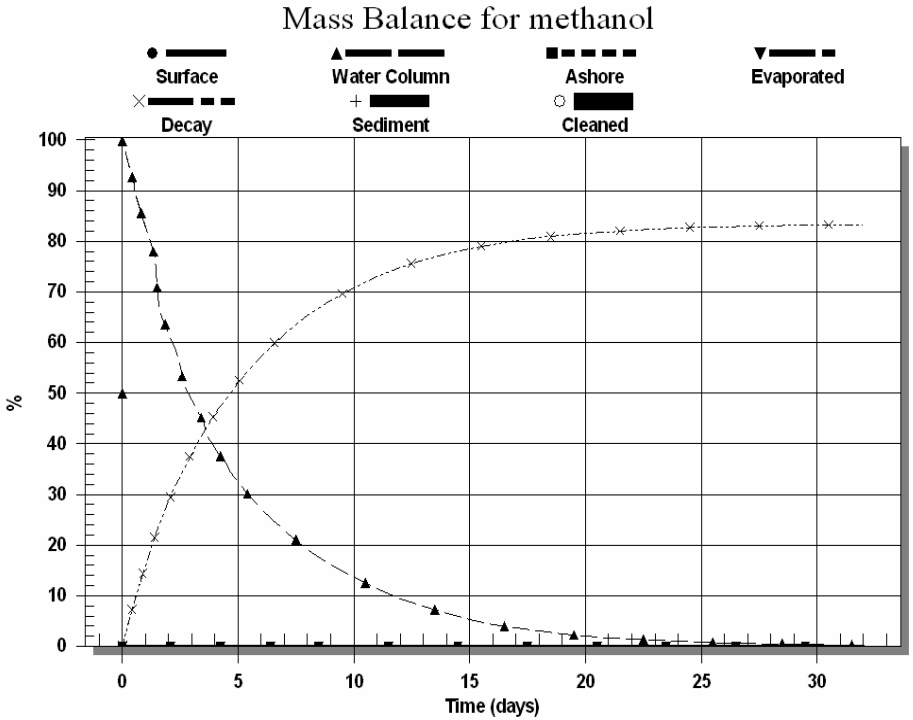
- Predicts trajectory/ fate of floating, sinking, evaporating, soluble and insoluble chemicals and product mixtures.

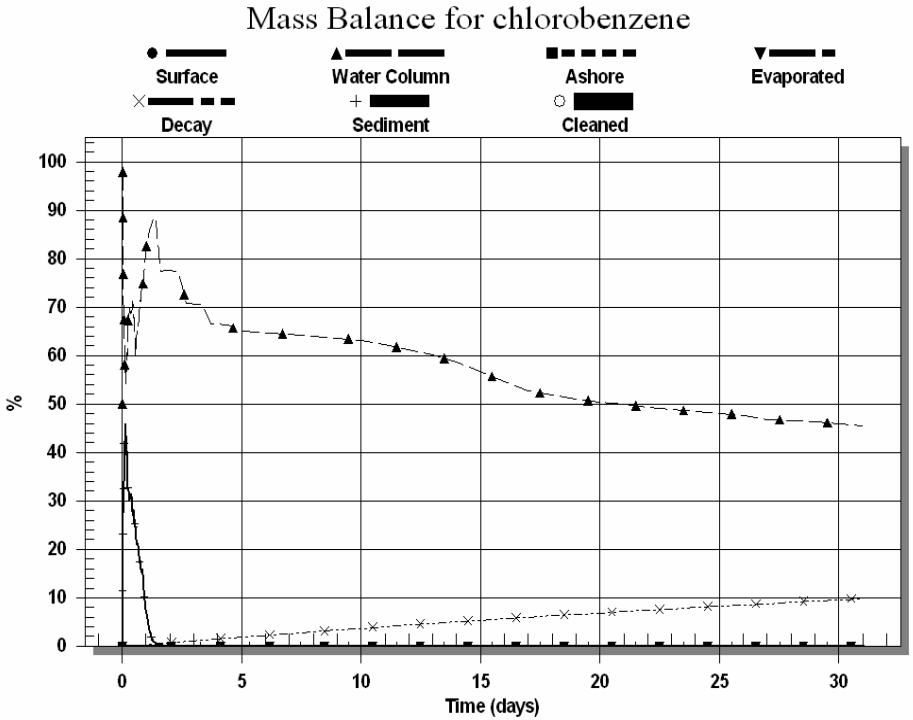
- Estimates the distribution of chemical elements on the surface, in the water column and in the sediments.

- Langrangian approach

CHEMMAP MODEL SELECTION OF CHEMICALS

	Methanol	Benzene	Ammonia	Chloro-benzene	TCE	Napthalene (gas)
Floatation	Floater	Floater	Floater	Sinker	Sinker	Sinker/ Air dispersed
Solubility	High	High	High	Normal	High	Semi
Volatility	High	High	High	Semi	Semi	None
Absorption	Dissolves	Moderate	Slight	Moderate	Moderate	Moderate
Flammability	High	High		High		High
Water/Air rapid interaction	No	No		No		No



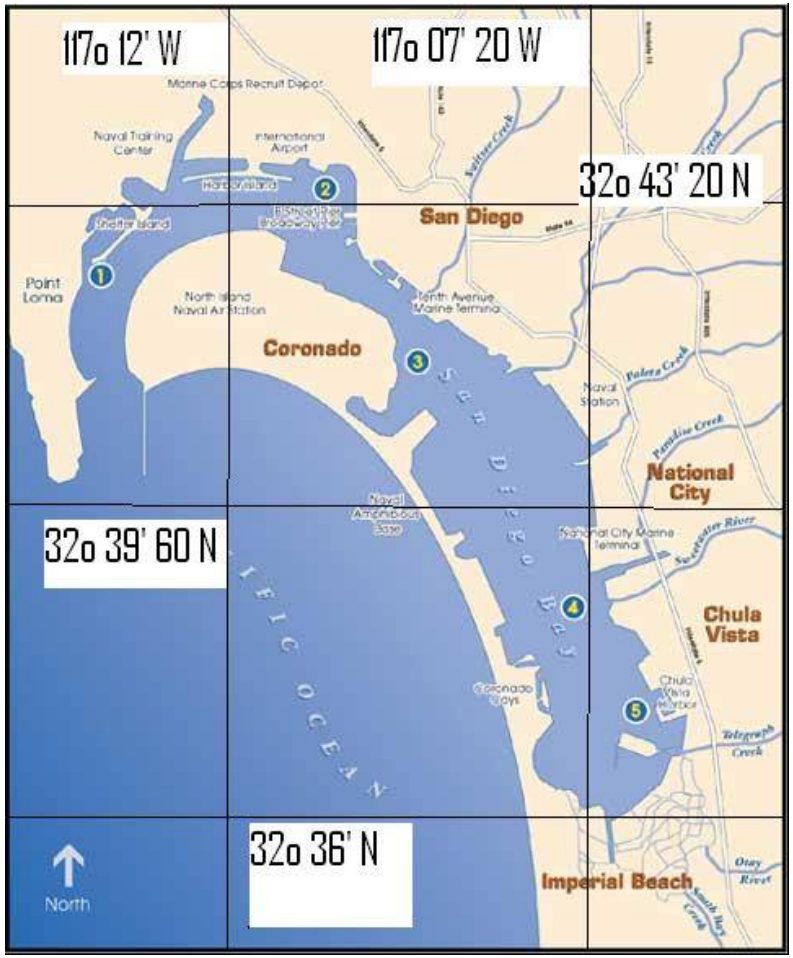


CHEMICAL THREAT SCENARIOS

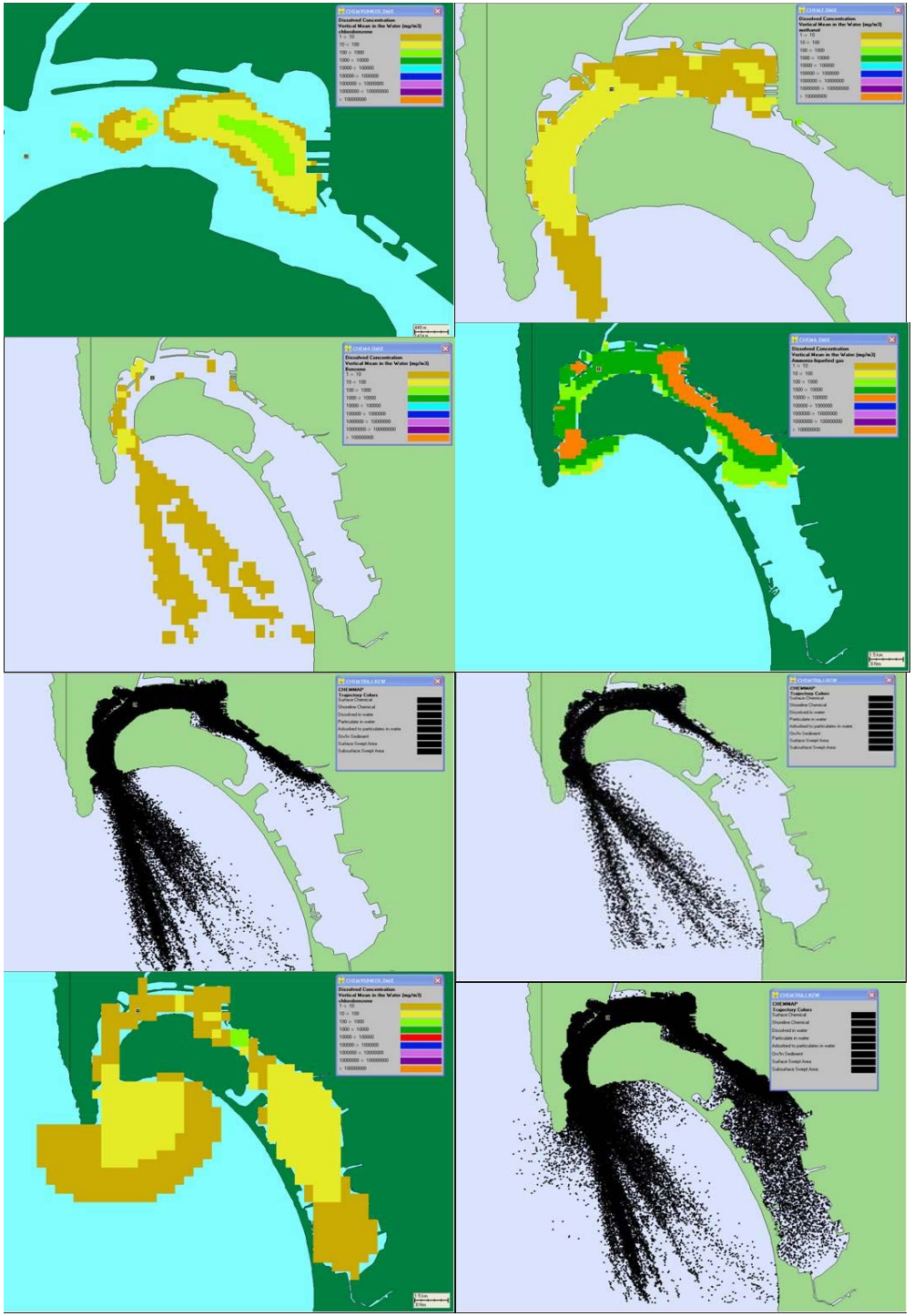
12 scenarios (6 chemicals in North and South San Diego Bay)

- 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

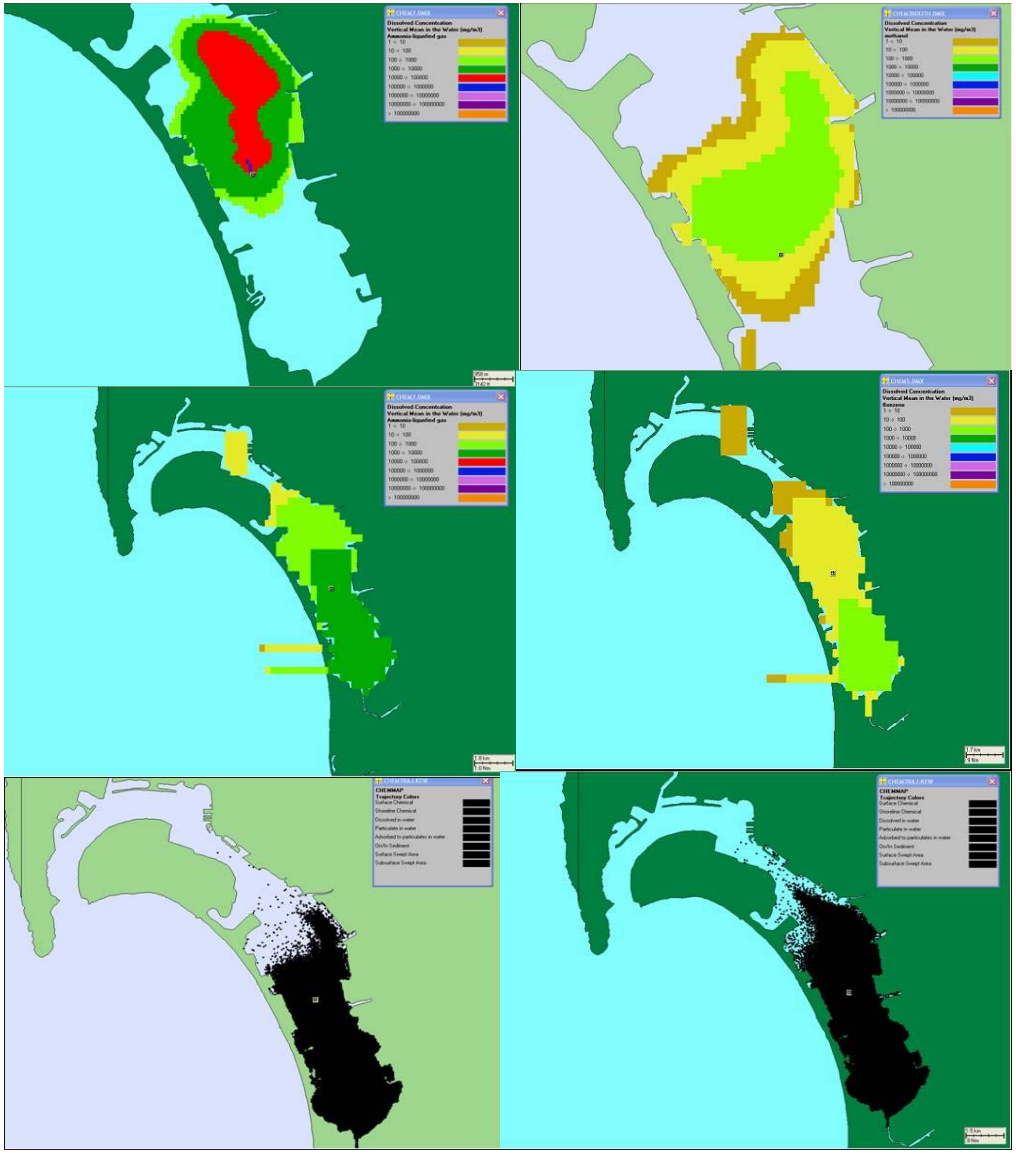


- North (location 2)
- South (location 4)
- Chemical release at 1 m depth



CHEMICAL THREAT SCENARIOS/ RESULTS NORTH SAN DIEGO BAY

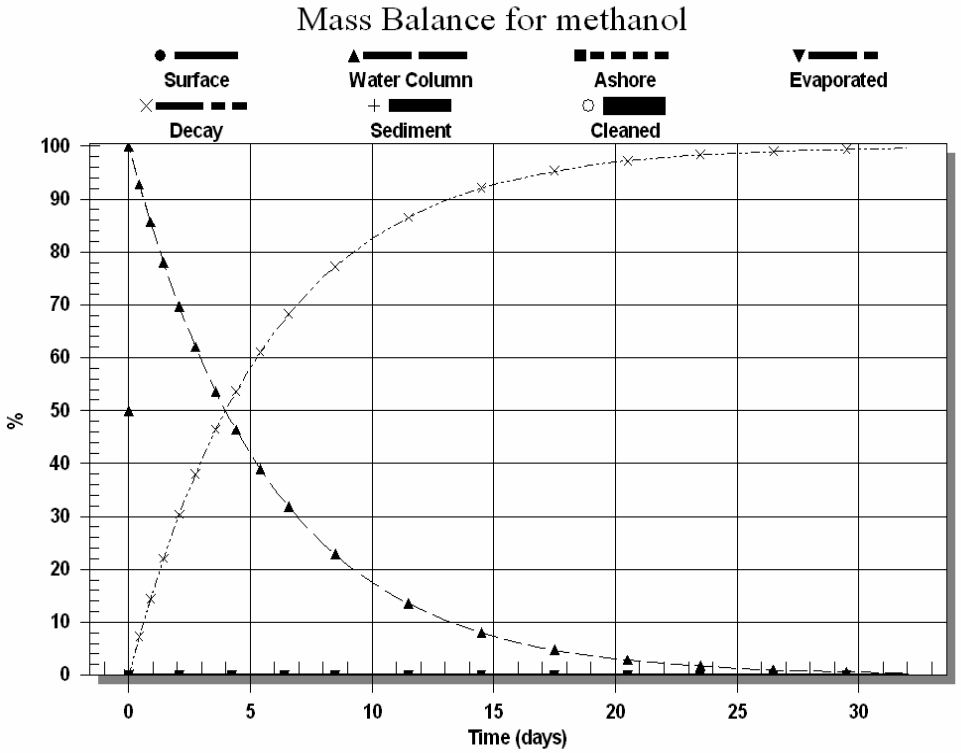
- 3 hours: San Diego port/city
- 10 hours: Entire North SD Bay
- 12 hours: Outside SD Bay
- 16-30 hours: Naval Station
- 5 days: Heavy impact on North Bay
- 20 Days: South Bay
- 32 Days: The entire SD Bay

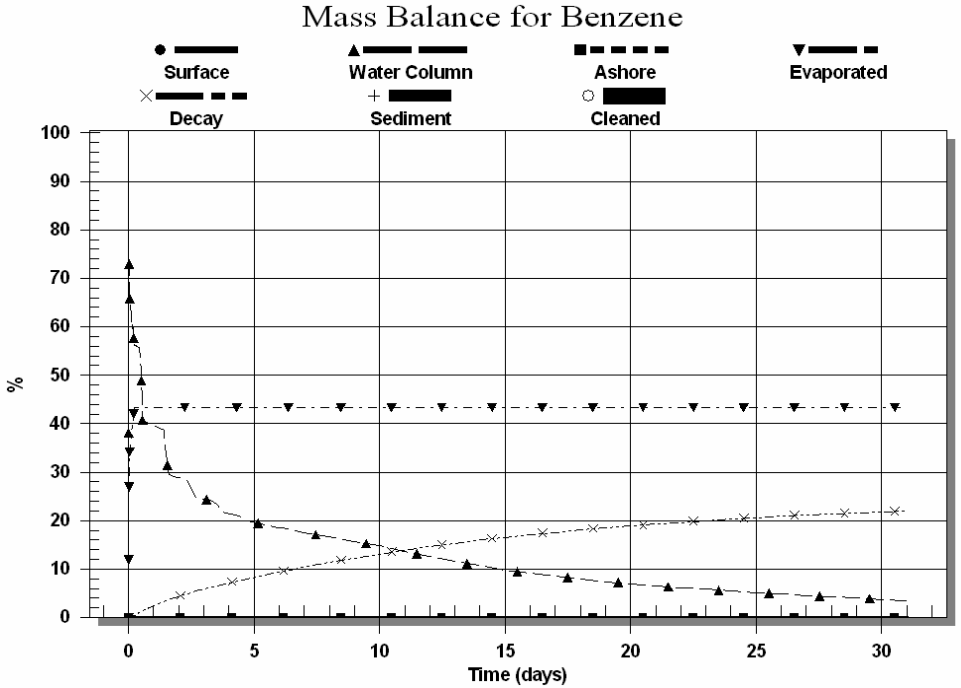


Comparison of different chemicals' results after spilling in South San Diego Bay

CHEMICAL THREAT SCENARIOS/ RESULTS SOUTH SAN DIEGO BAY

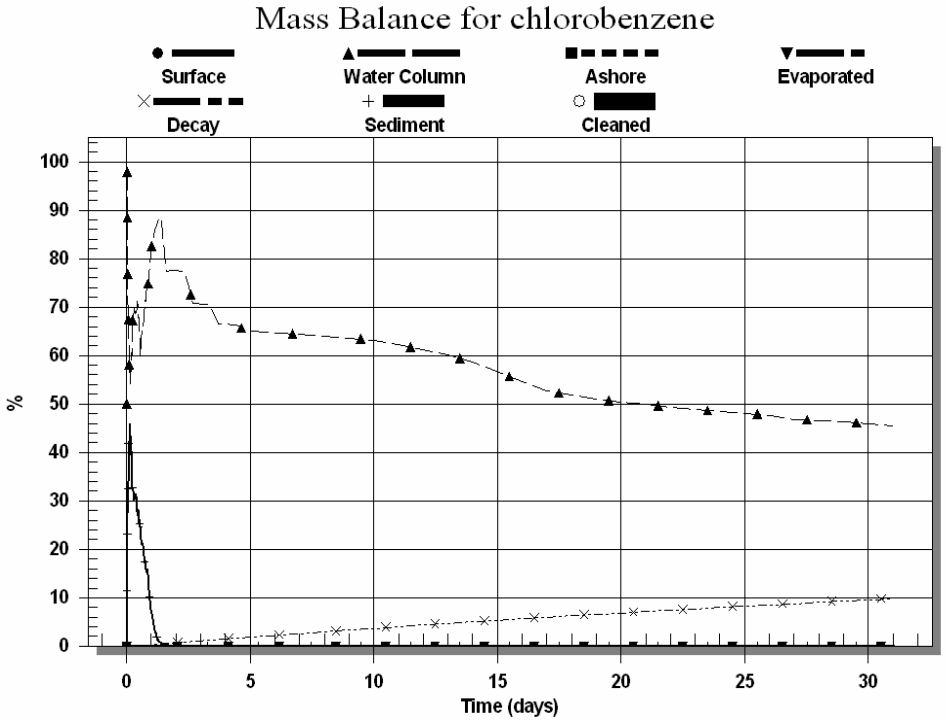
- 12 hours: Naval Station
- 15-17days: Small part of absorbed or dissolved chemical in San Diego city/port
- After 32 days: No effect to North San Diego Bay

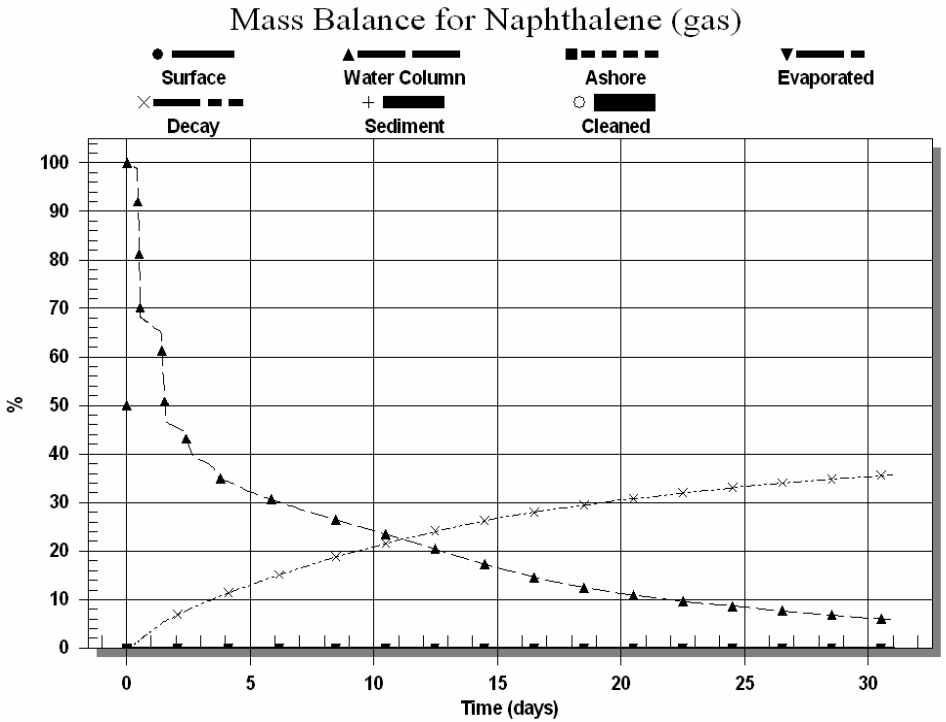




CHEMICAL THREAT SCENARIOS RESULTS FOR FLOATERS

- 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