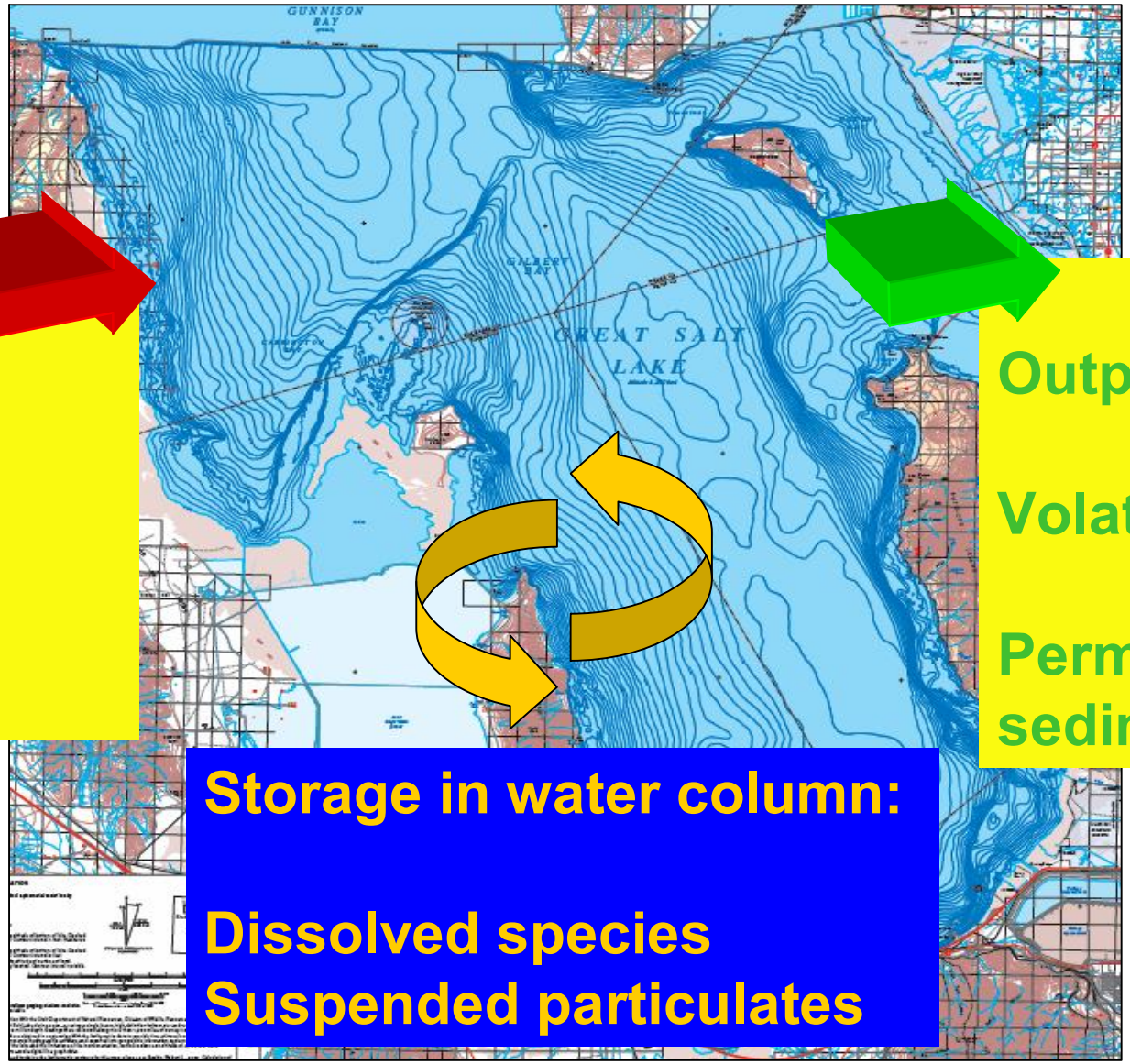
Se Flux in the S. Arm



Inputs:

Rivers & streams

Outputs:

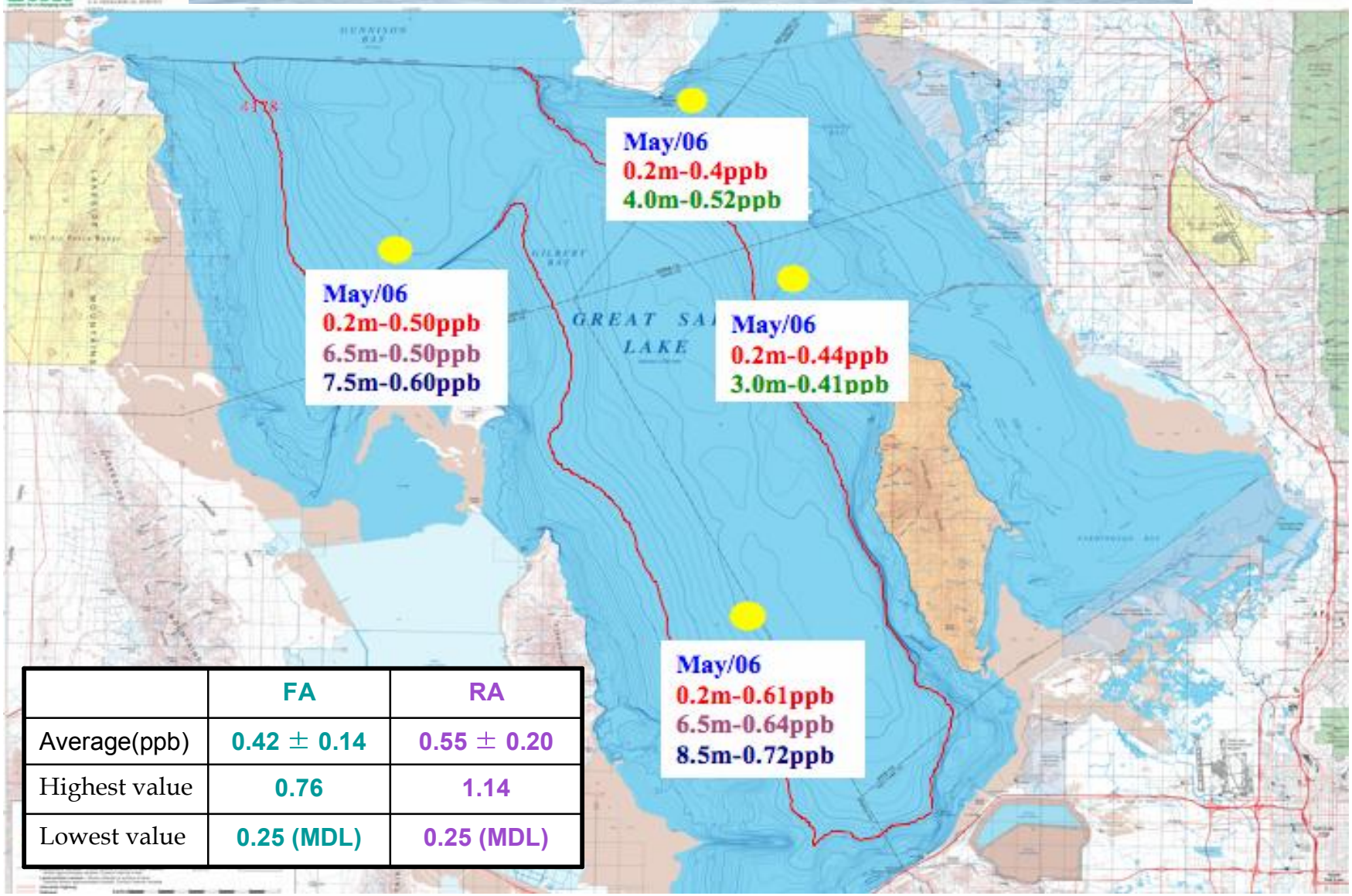
Volatilization

Permanent sedimentation

Storage in water column:

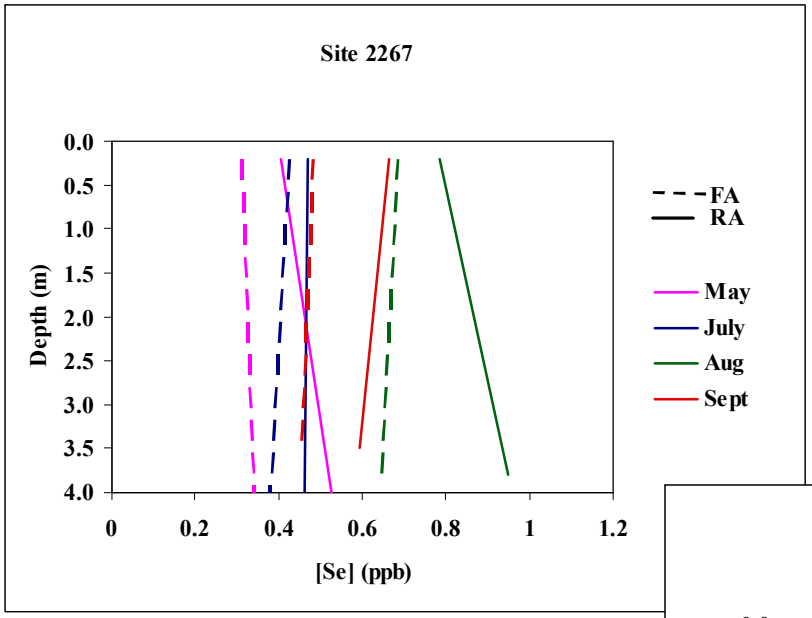
Dissolved species
Suspended particulates

Total Se in Water

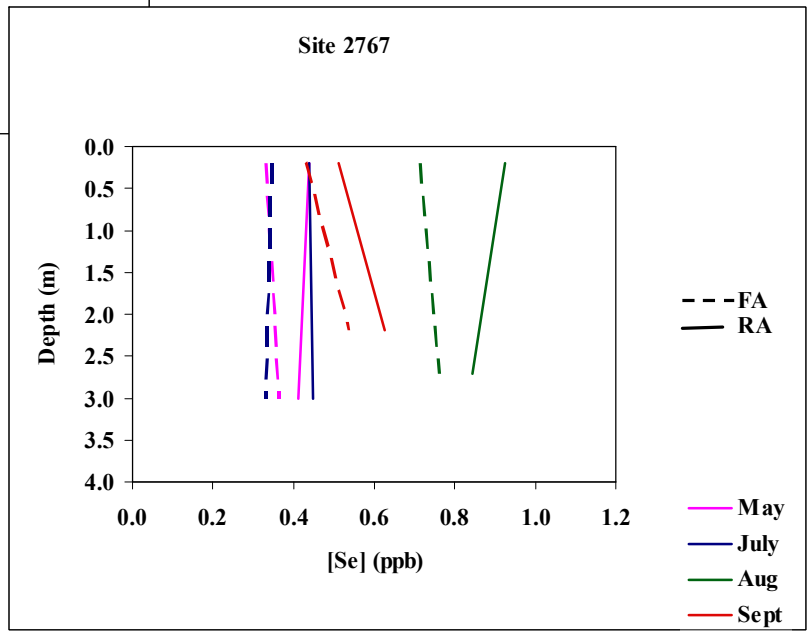


	FA	RA
Average(ppb)	0.42 ± 0.14	0.55 ± 0.20
Highest value	0.76	1.14
Lowest value	0.25 (MDL)	0.25 (MDL)

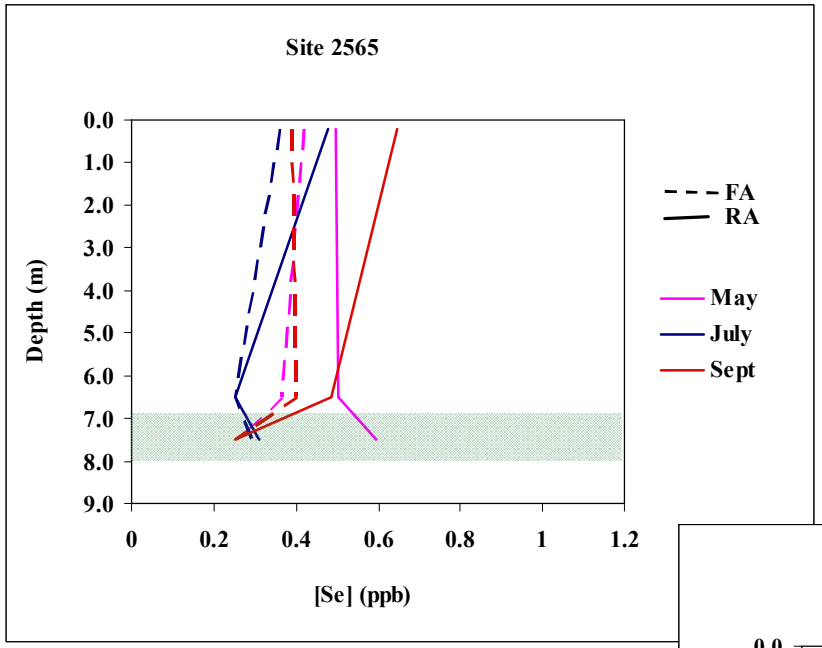
Se Conc's in Shallow Layer



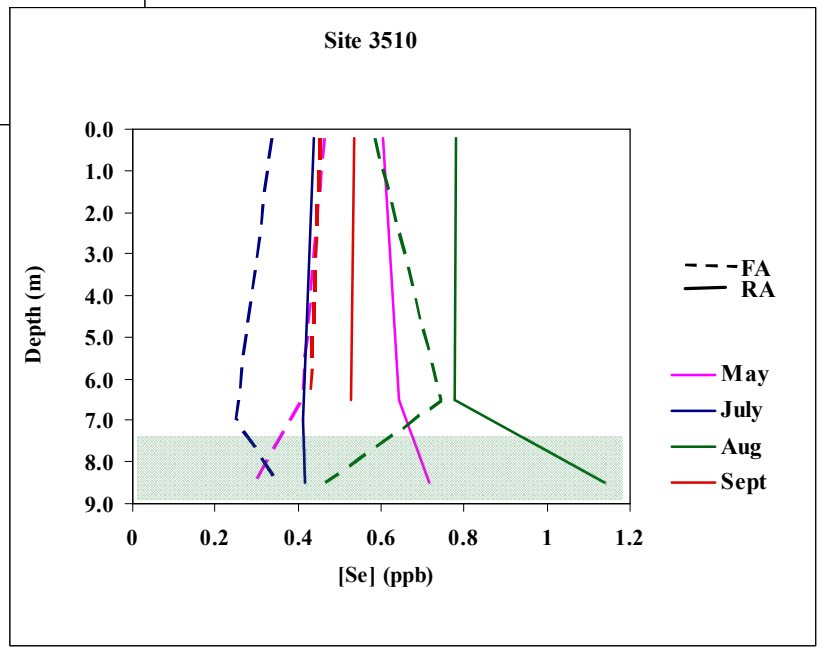
Shallow Layer



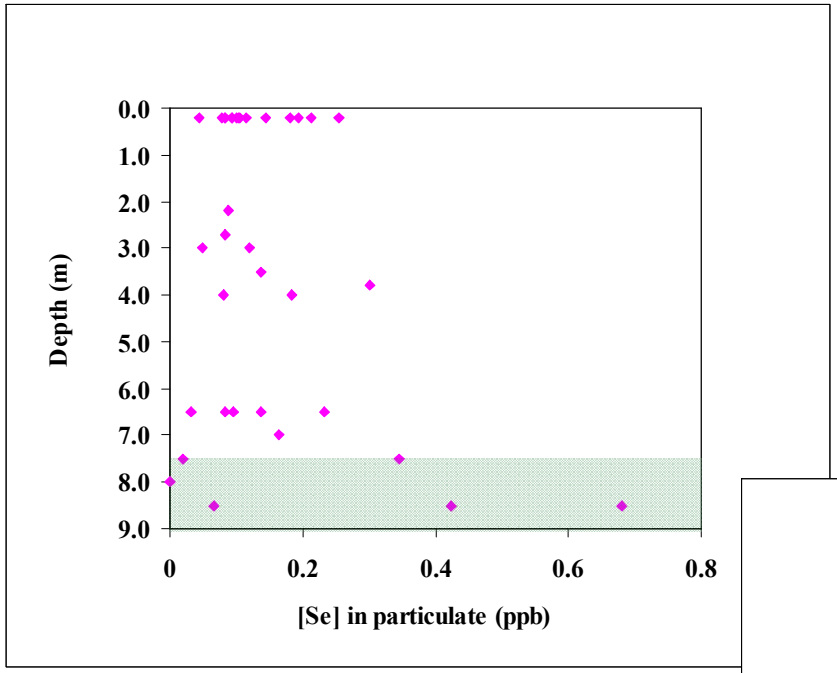
Se Conc's over Entire Depth

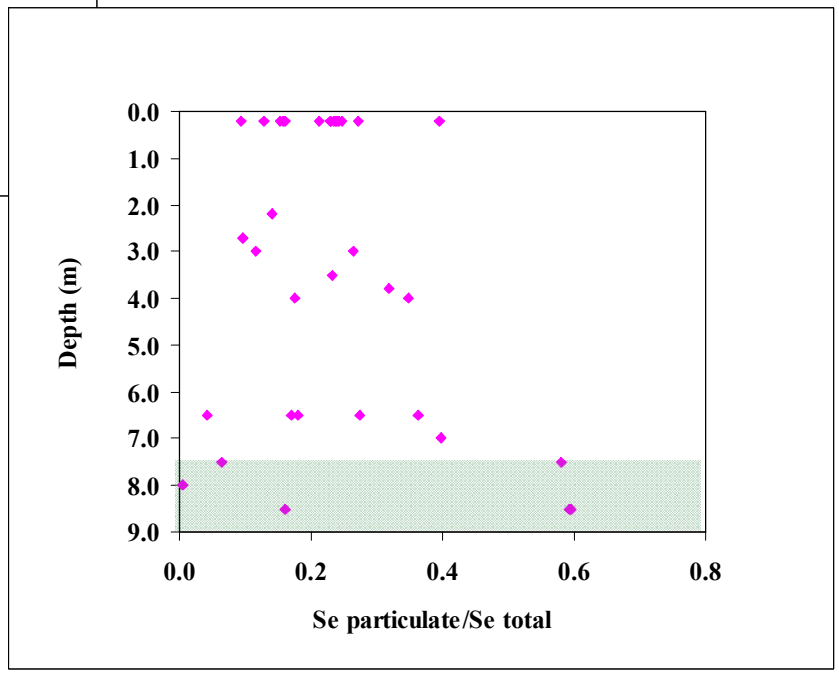


Shallow and deep brine layers

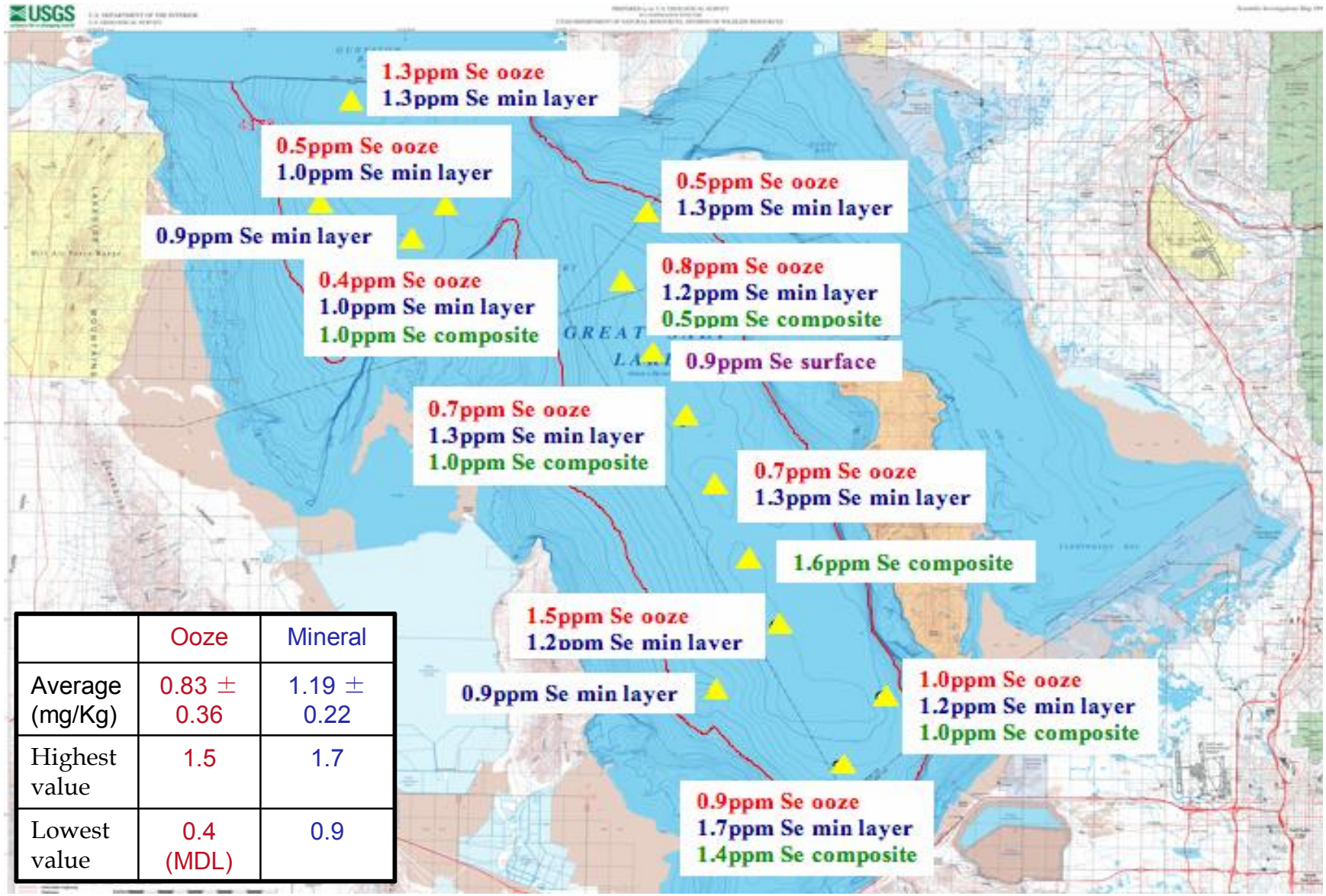


Se particulate in Water



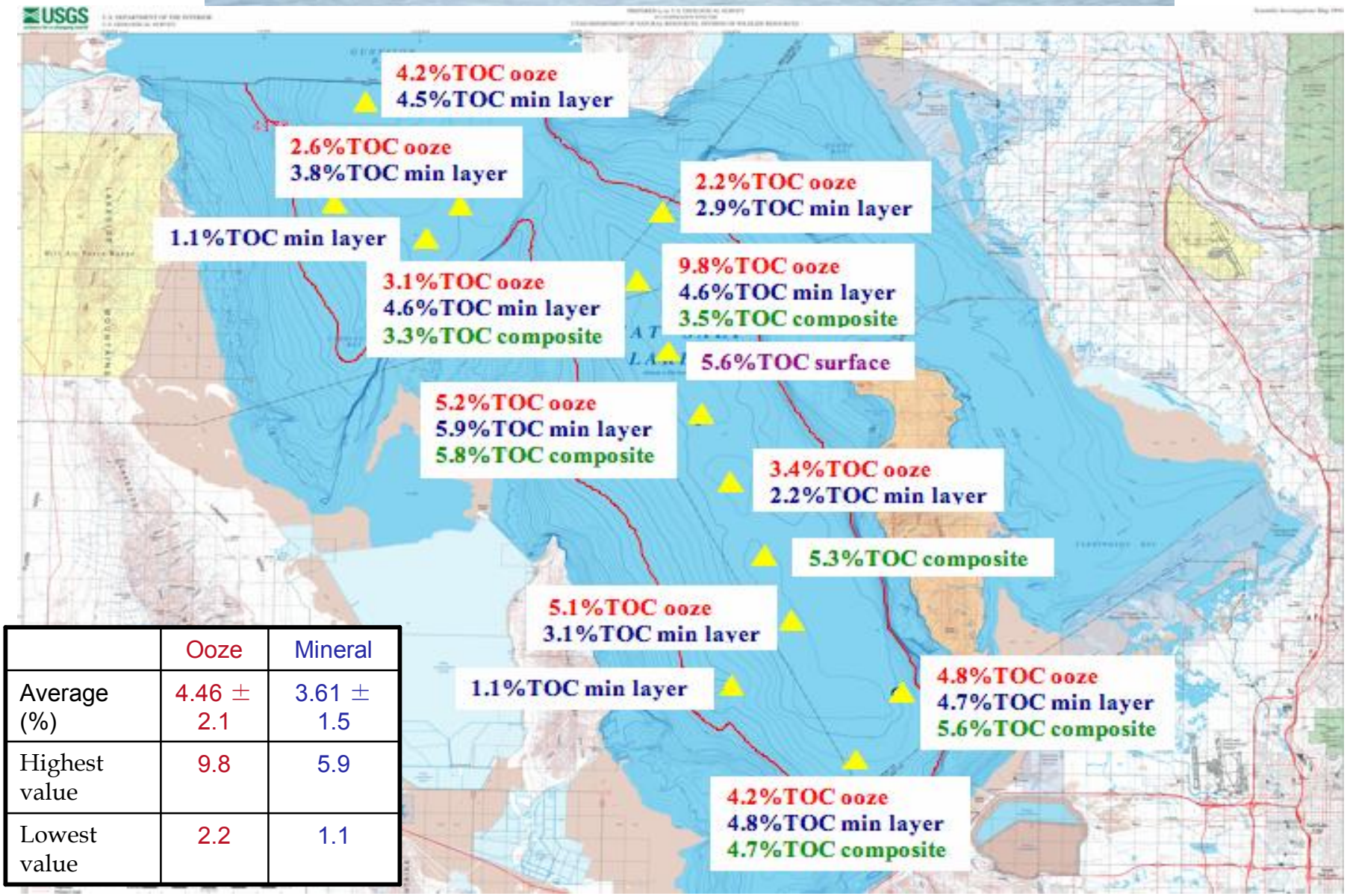


Se Conc's in Sediment



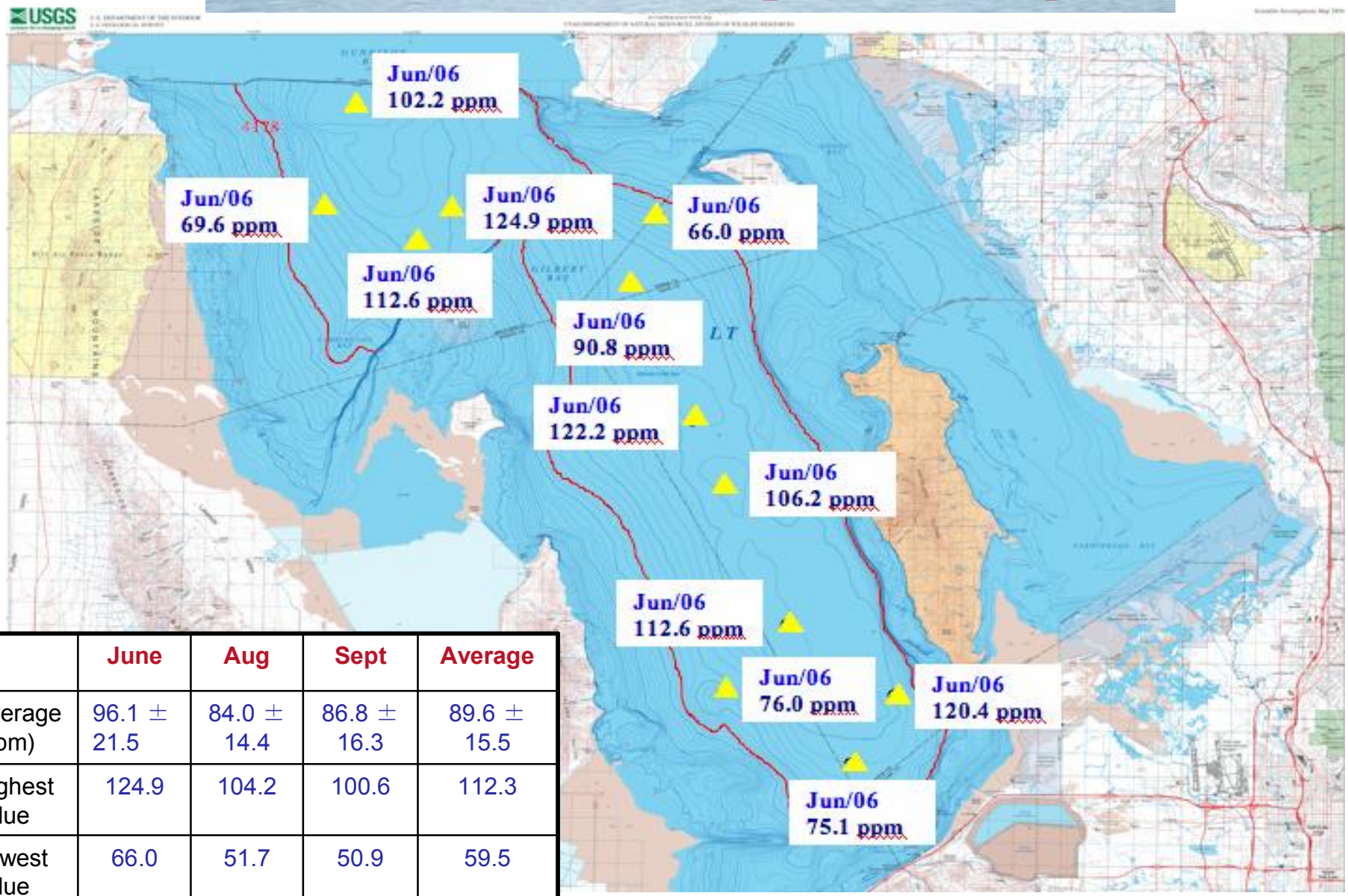
	Ooze	Mineral
Average (mg/Kg)	0.83 ± 0.36	1.19 ± 0.22
Highest value	1.5	1.7
Lowest value	0.4 (MDL)	0.9

TOC Conc's in Sediment



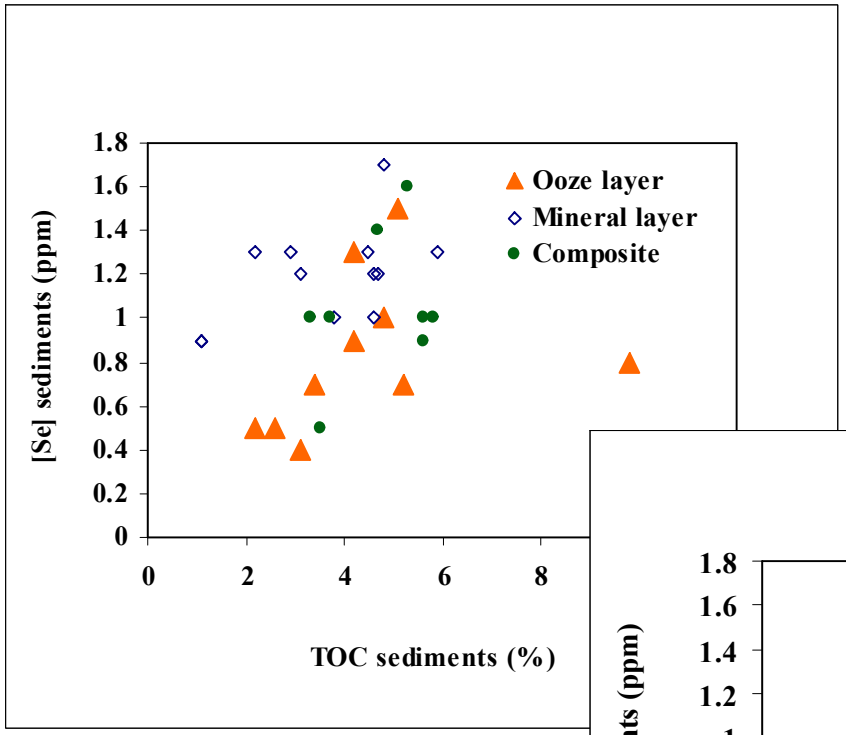
	Ooze	Mineral
Average (%)	4.46 ± 2.1	3.61 ± 1.5
Highest value	9.8	5.9
Lowest value	2.2	1.1

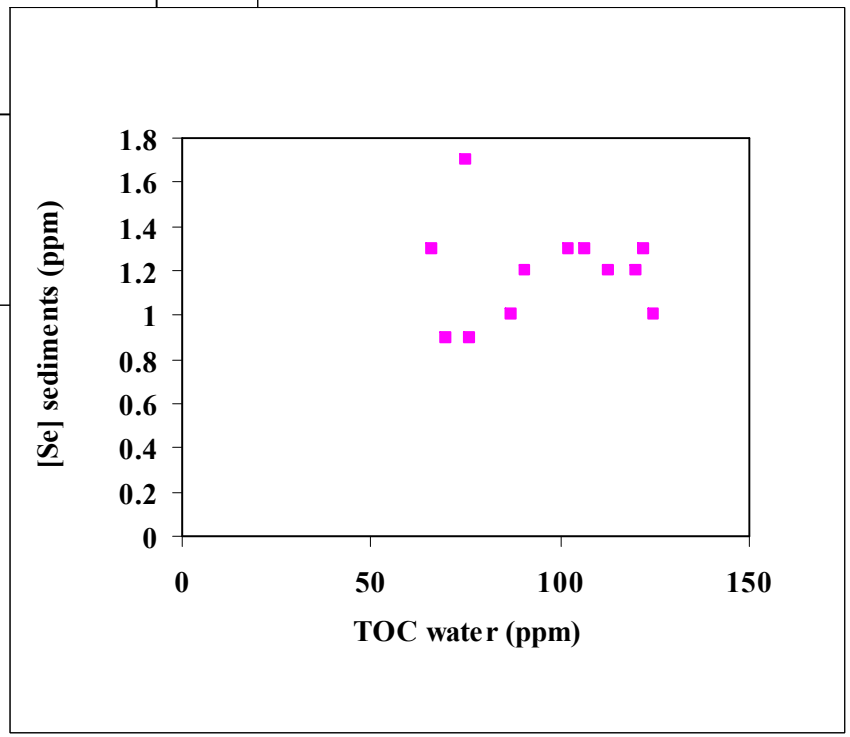
TOC Conc's in Deep Brine Layer



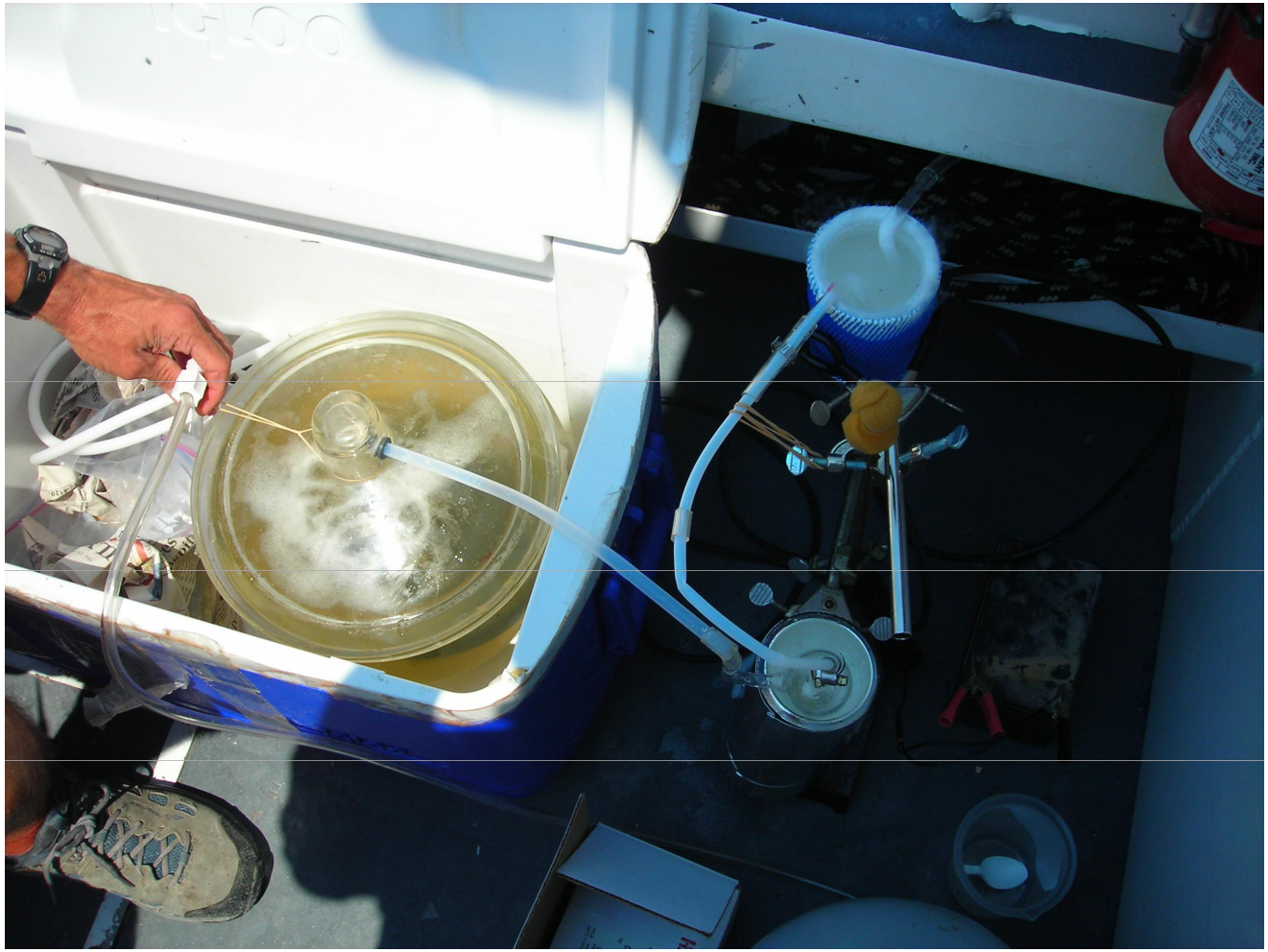
	June	Aug	Sept	Average
Average (ppm)	96.1 ± 21.5	84.0 ± 14.4	86.8 ± 16.3	89.6 ± 15.5
Highest value	124.9	104.2	100.6	112.3
Lowest value	66.0	51.7	50.9	59.5

Se Sediment vs TOC





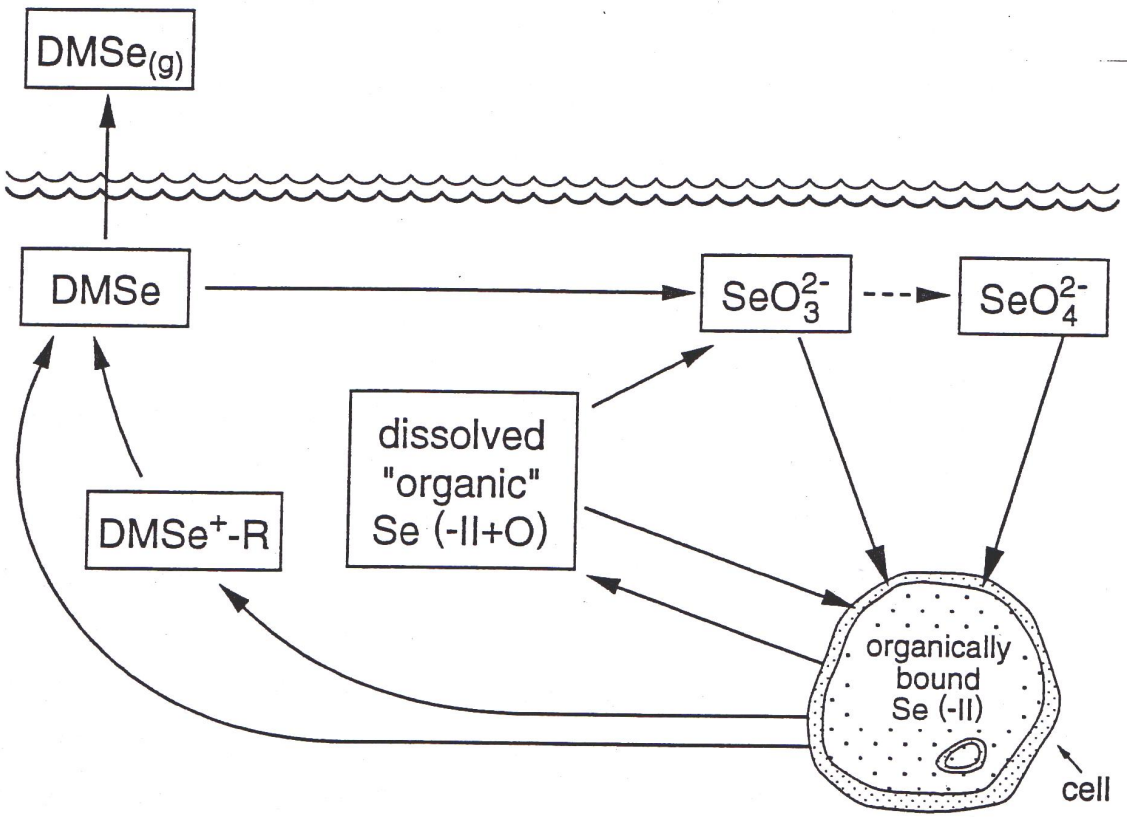
Volatilization of Se



Introduction

- Se volatilization may be major mechanism of permanent selenium removal from the Great Salt Lake
- Volatilization flux of selenium from the GSL has not been previously measured due to challenges of analysis in this hyper-saline environment.

Biotransformation of Se



(Cooke and Bruland, 1987)

Biomethylation of Se

- Microorganisms
- Fungi
- Terrestrial plants
- Mammals

(Karlson and Frankenberger, 1993)

- Phytoplankton
- Zooplankton
- Microalgea
- Aerobic and anaerobic microorganisms

(Amouroux, 1995)

Importance of volatile Se

- Estimated annual gaseous Se flux from the Mediterranean Sea to the atmosphere:

  190 t/year of TVSe

- Greater than the emission resulting from European countries anthropogenic activities:

  75 t/year

(Amouroux and Donard, 1996)

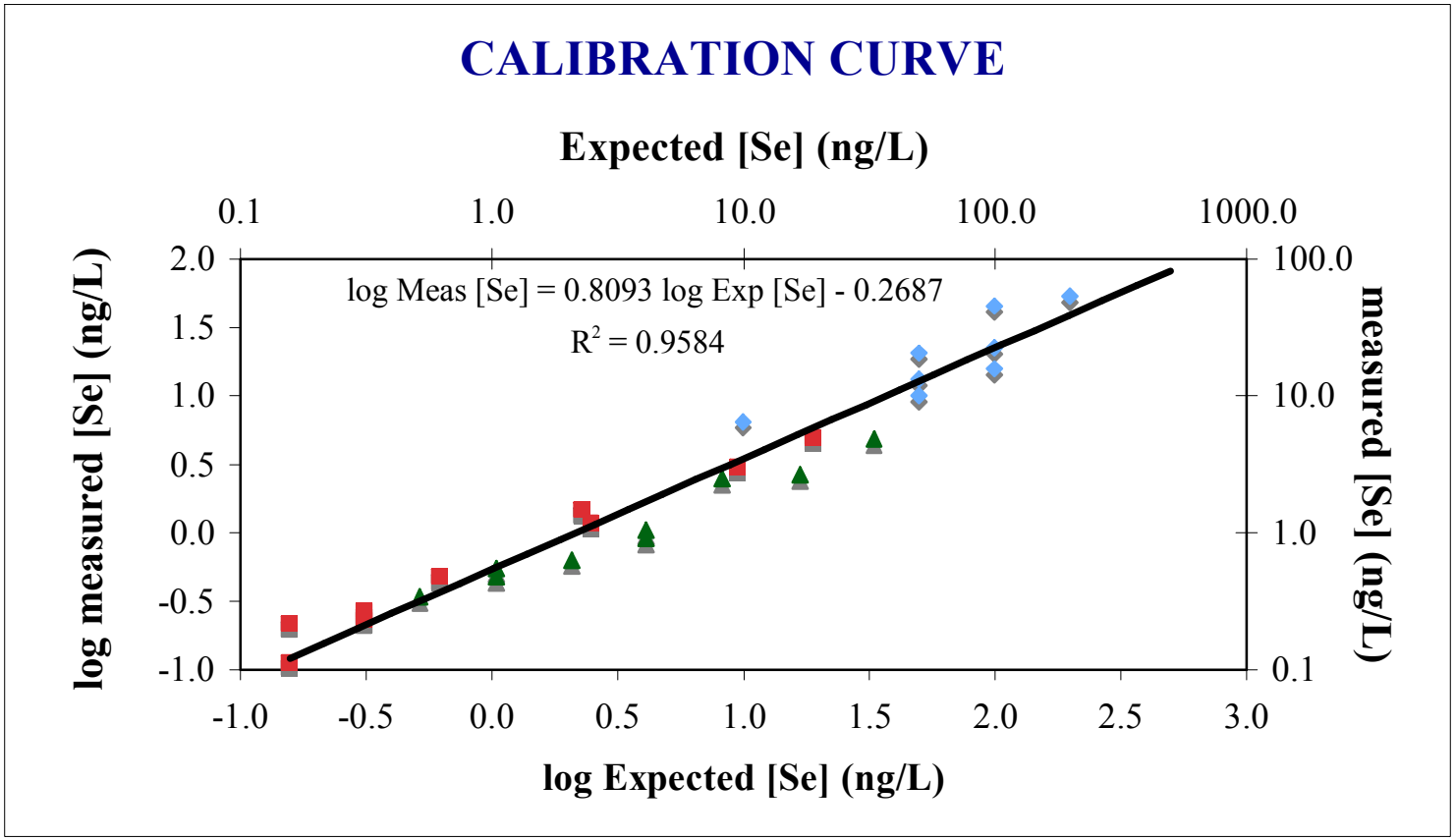
PURGE AND TRAP SYSTEM

- Sparge water with He and collect in a cryogenic trap
- Reactor (modified dessicator) for 7L of water
- Cryogenic system: water trap (dry ice + EtOH) and sample U trap (liq. N_2)

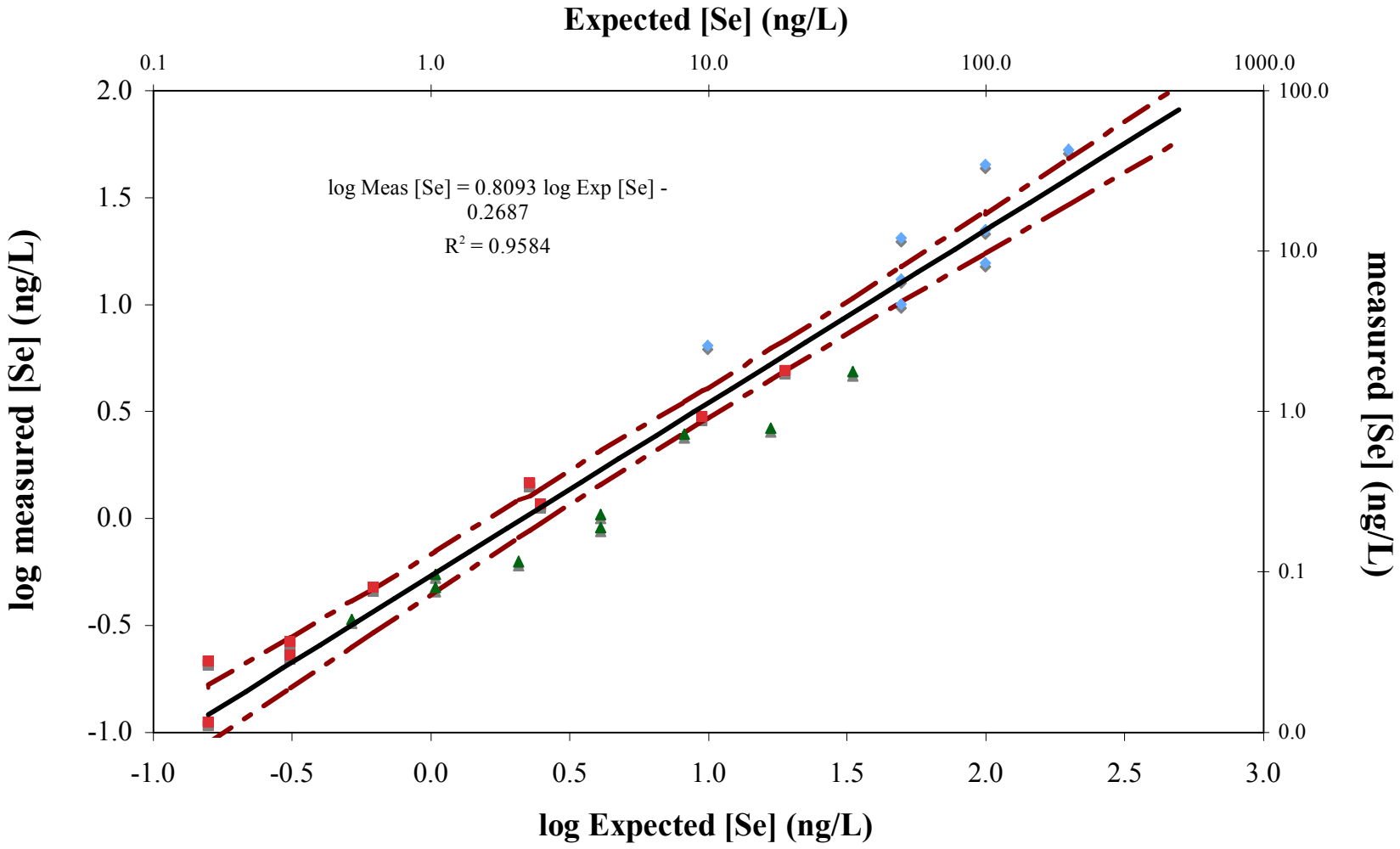
Purge & Trap System

Calibration

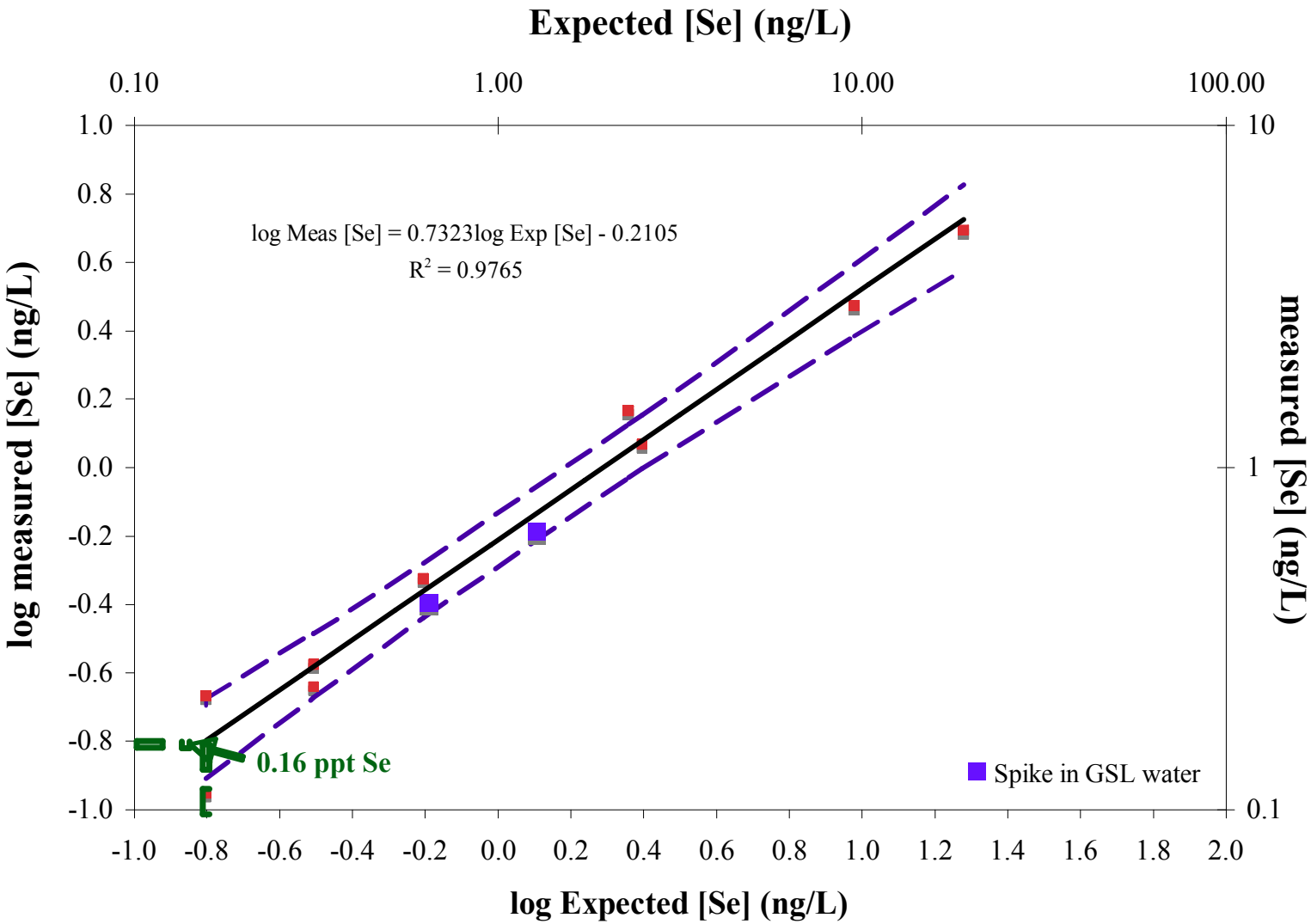
- Calibration using pure volatile Se compound (DMeSe)



Calibration II



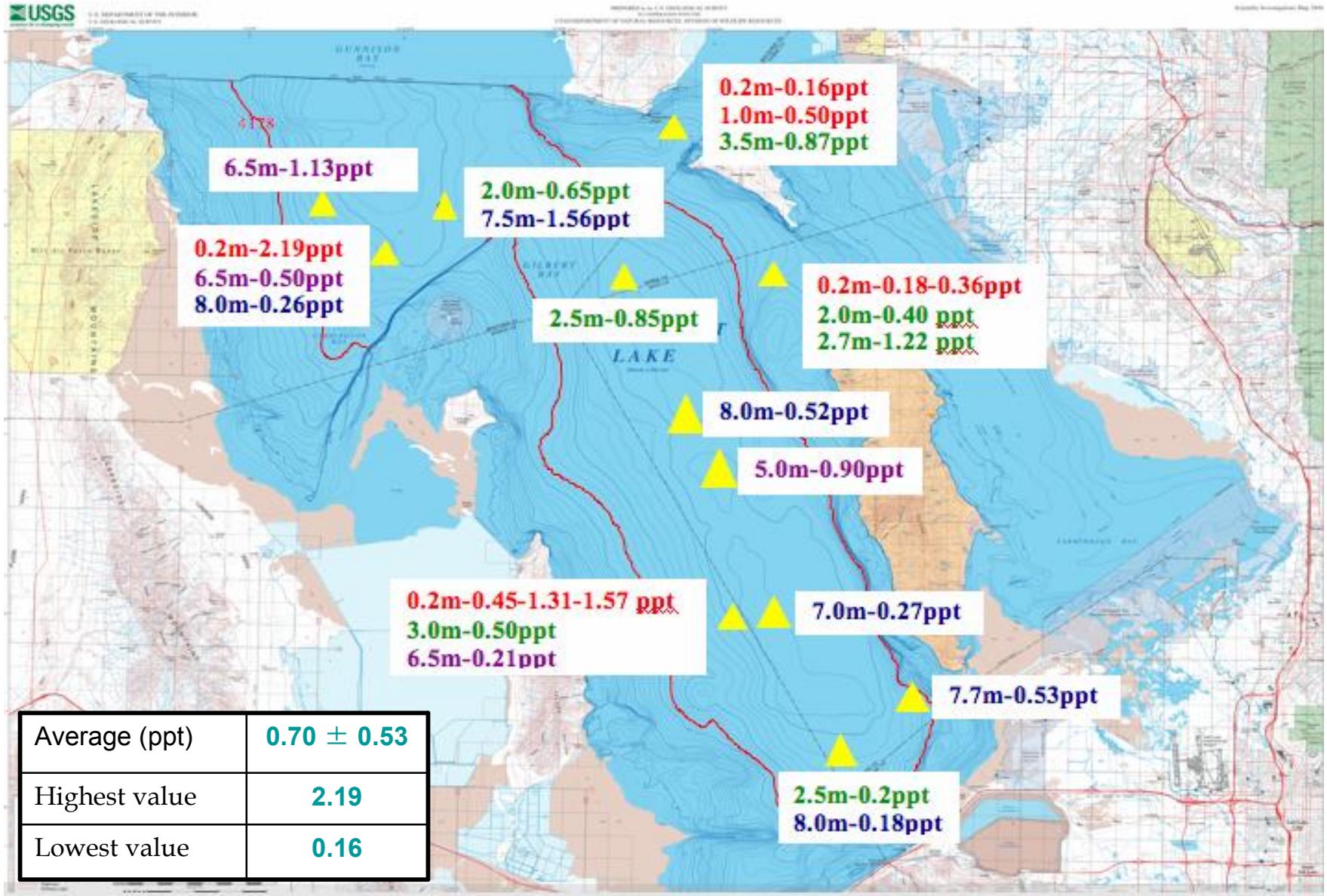
Calibration III



Conditions

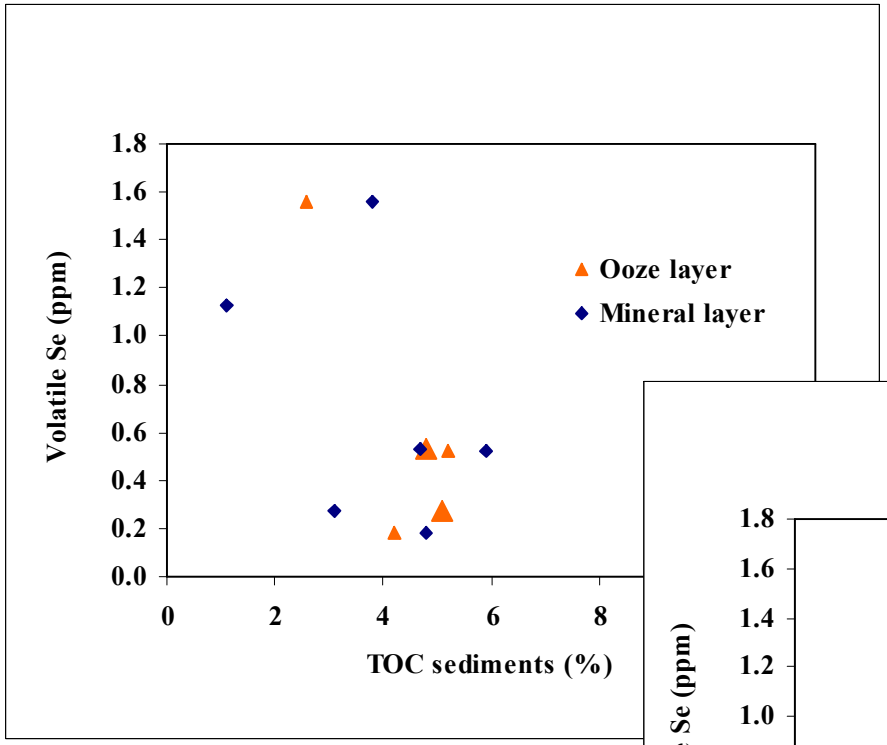
- Clean procedure for system: HNO_3 + DI water
- Purging time: 15 min
- He flow around 300 mL/min
- Sample oxidized with HNO_3 and digested at 75°C for 3 hours
- Analyzed in the ICP-MS

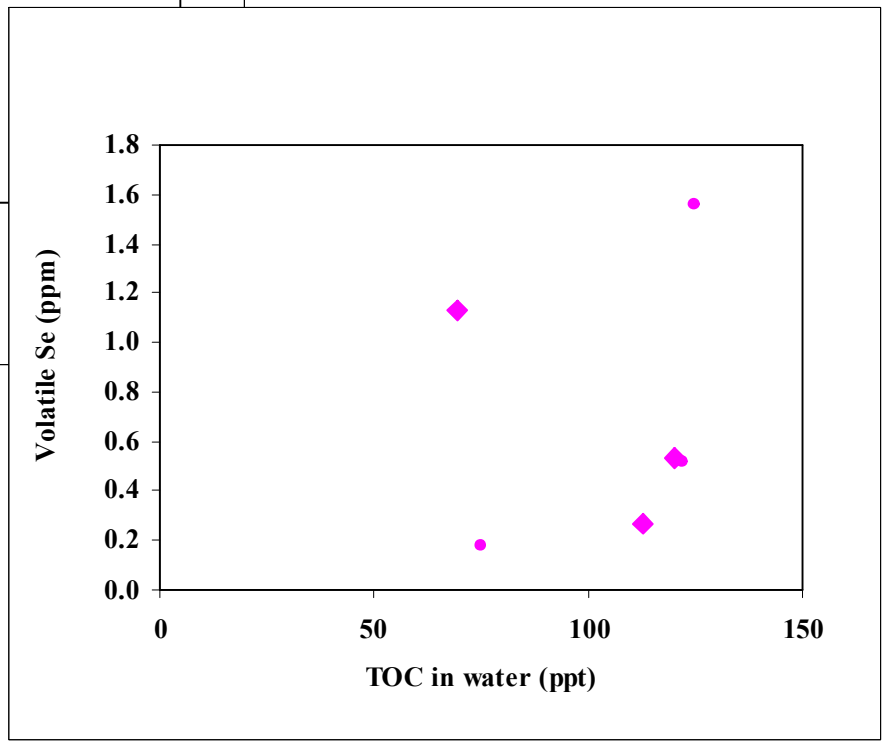
Volatile Se conc's



Average (ppt)	0.70 ± 0.53
Highest value	2.19
Lowest value	0.16

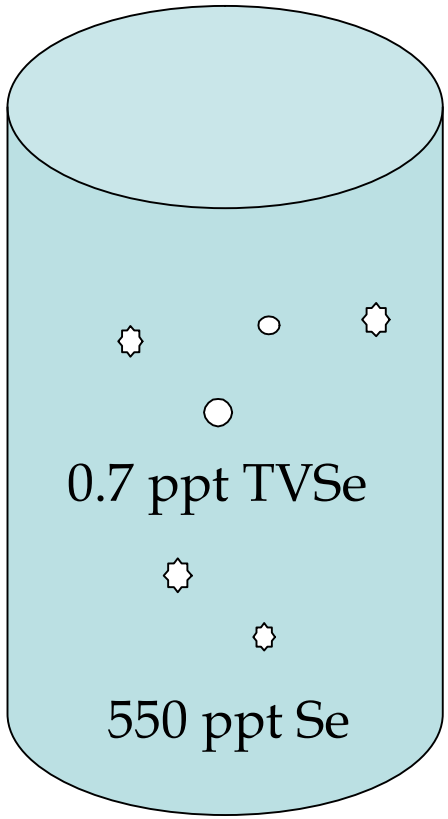
Se Volatile vs TOC



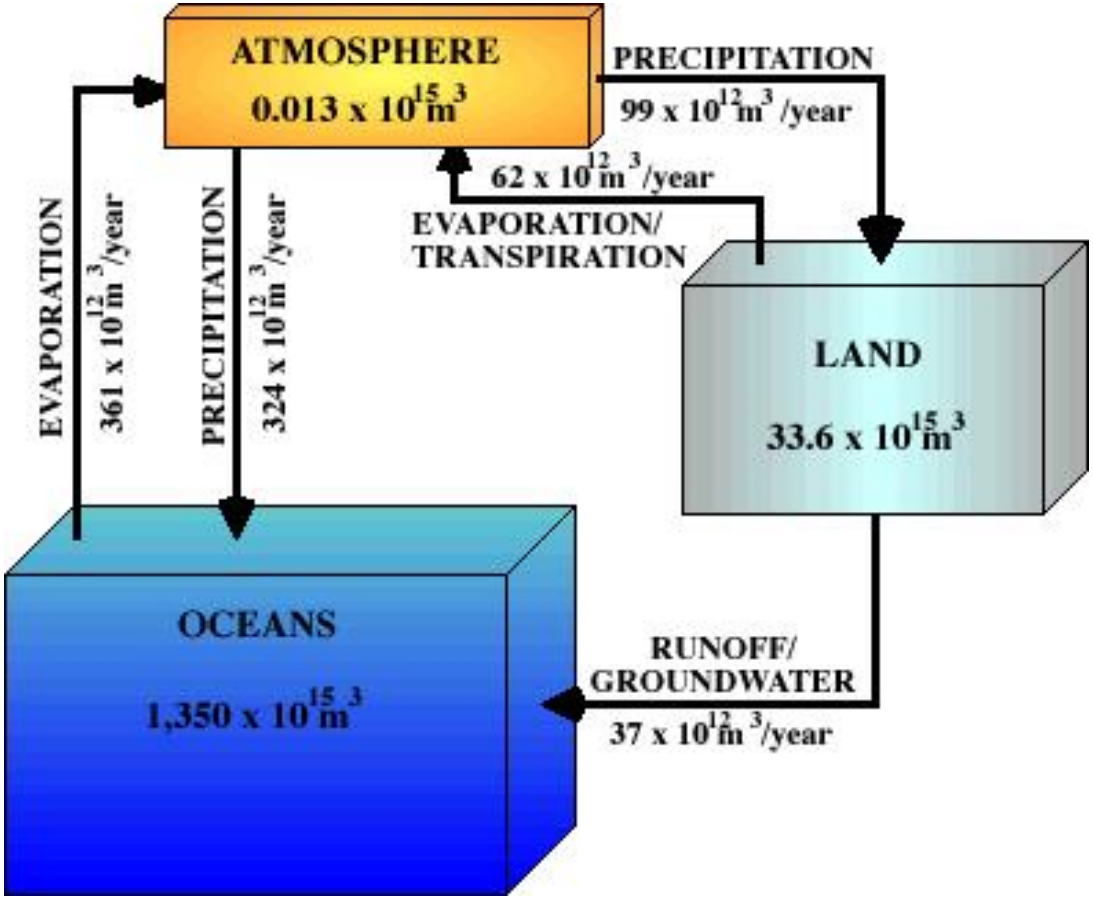


Significance of volatile Se

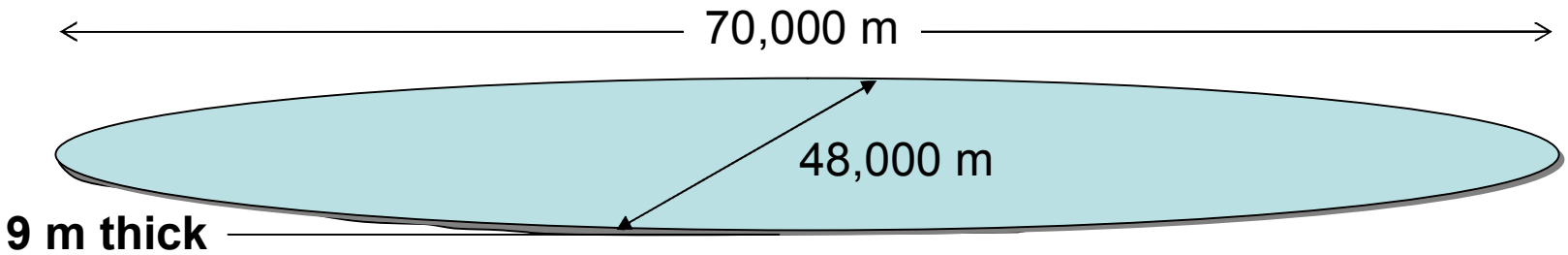
- Mass Volatile Se in water : 6.5 Kg
- Mass Total Se in water : 5,000 Kg
- %(Volatile Se/Total Se) : 0.13 %



Water Budget



Water vapor in atmosphere : 0.001%



455,190 acres
7,574,000 acre-ft

Example fluxes

Residence time (d)	Volatile Se (Kg/yr)	Removed/total
10	237	1/21
1	2,372	1/2
0.1	23,725	4.7

Flux calculations

- Flux from well-mixed lake

Conc. Volatile Se in water (measured)

Conc. Volatile Se in air (measured)

$$Flux = k_w \left(C_{water}^{VSe} - \frac{C_{air}^{VSe}}{K_{H'_{GSL}}} \right) \text{ in mol m}^{-2} d^{-1}$$

water gas transfer velocity (calculated)

Henry's constant (calculated)

Henry's constant

Effect of salt content

- Henry's constant of DMeSe at 25°C for fresh water:
  1.35 ± 0.37 atmL/mol *(Amouroux, 1995)*

$$K_{H'_{GSL}} = K_{H'_w} .10^{K^s_{DMSe}[salt]_{tot}}$$

- Henry's constant od DMeSe at 25°C corrected for the GSL salinity: 3.52 atmL/mol

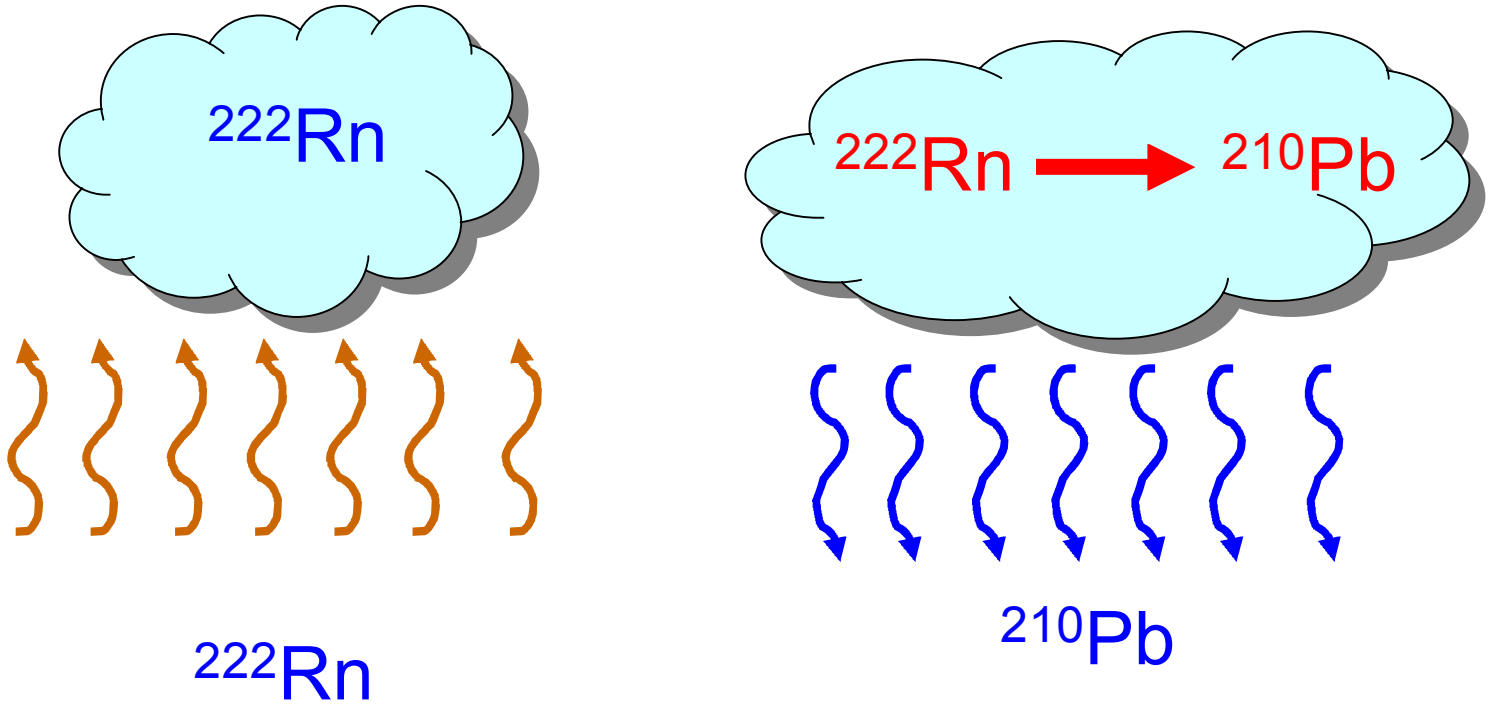
- INCREASE BY A FACTOR OF 3

USGS
science for a changing world

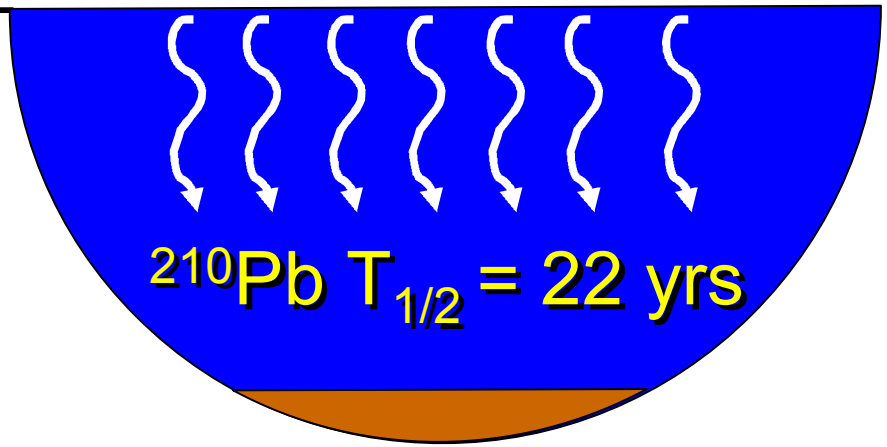
Need a floating flux chamber !

THE UNIVERSITY OF UTAH

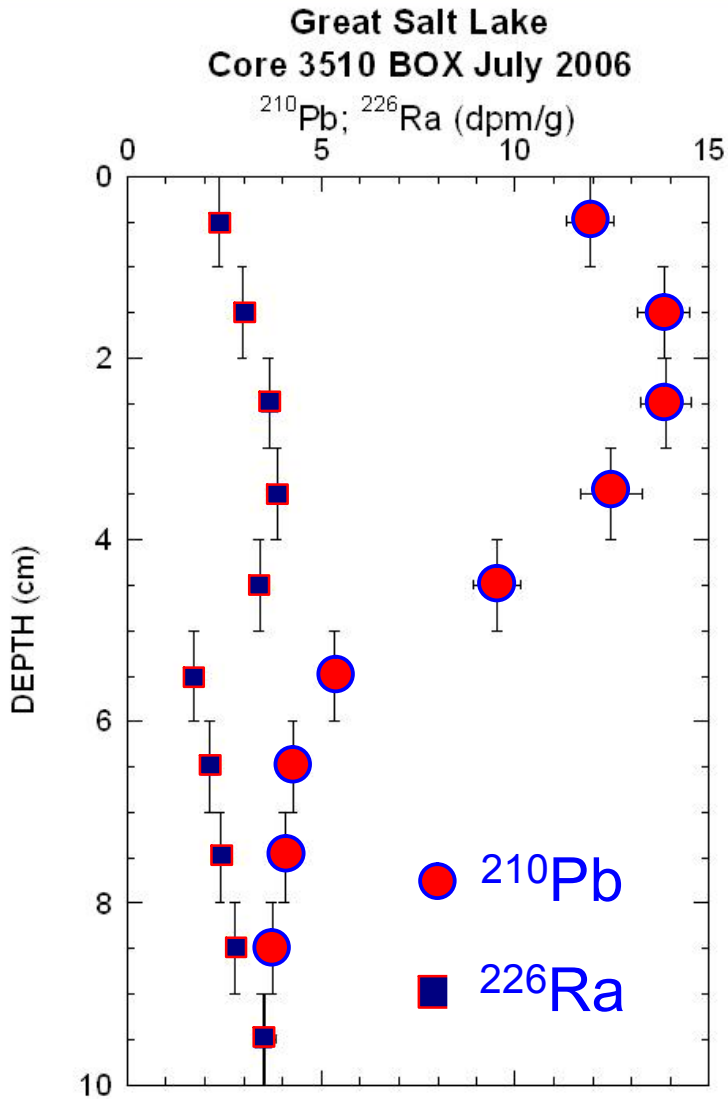
Permanent Sedimentation



Radon emissions from land surface



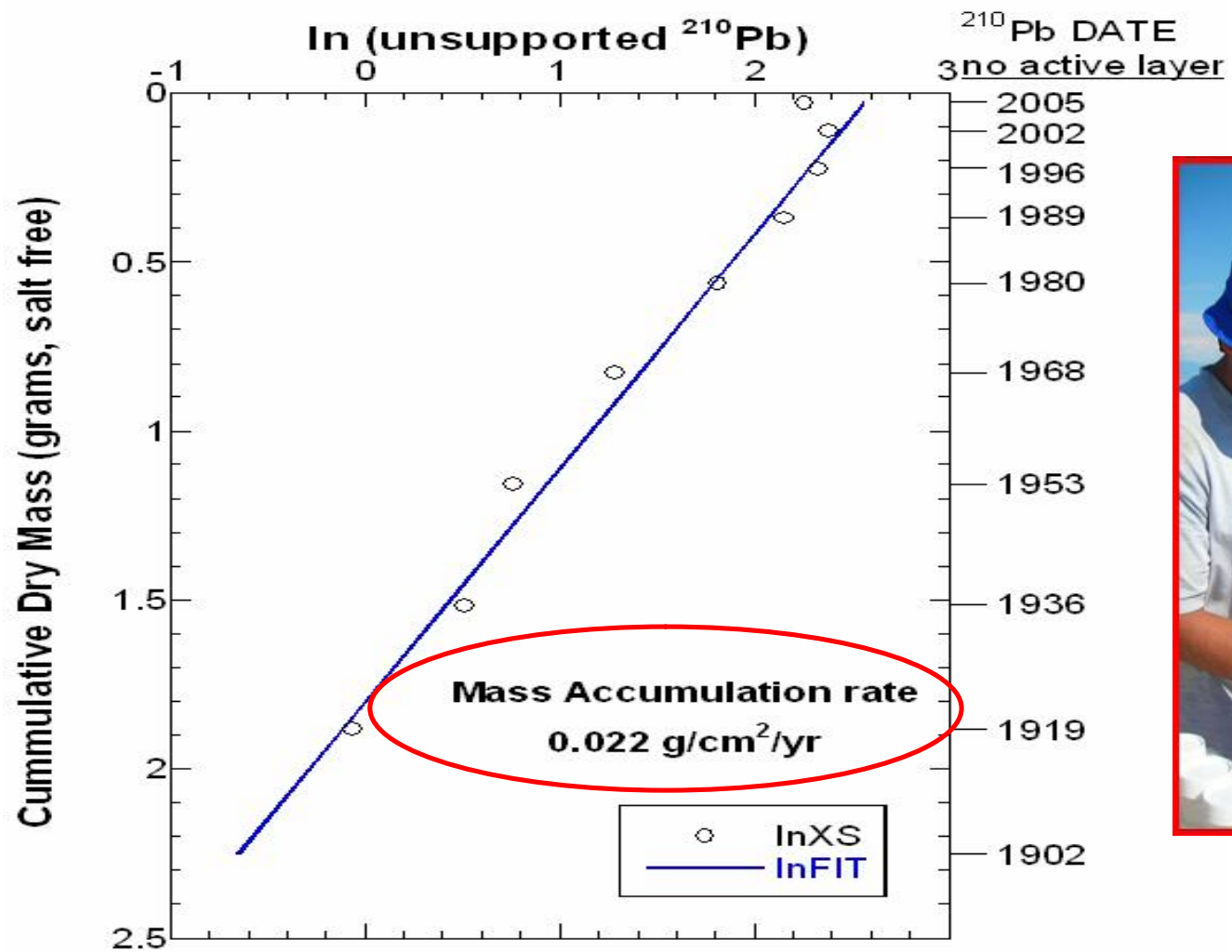
Permanent Sedimentation



Unsupported ^{210}Pb

$^{210}Pb - {}^{226}Ra$

Permanent Sedimentation



Selenium sedimentation rate:

Waiting for Se concentrations from cores (LET and UU labs)

Storage in Water Column

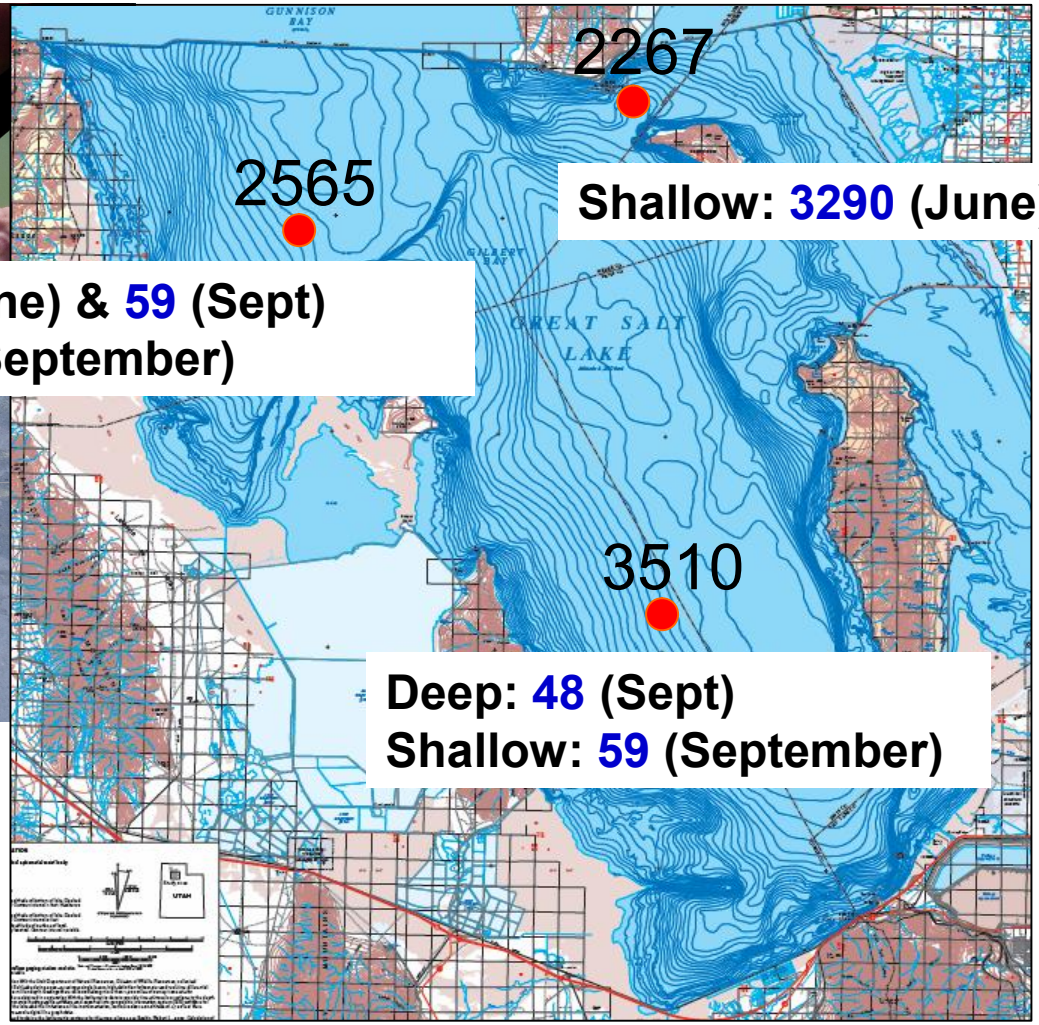
Downward sedimentation

Re-suspension

Mixing and re-solubilization

Downward Sedimentation

Downward sediment flux mg/cm^2/yr



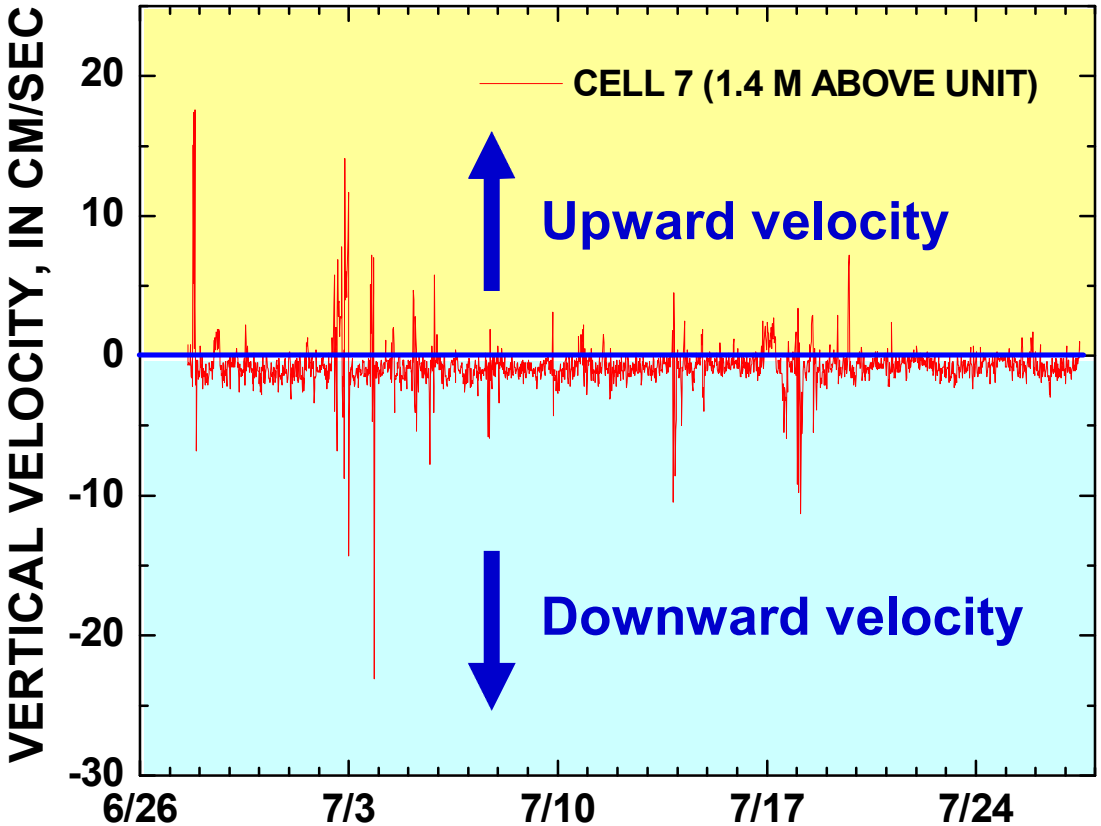
^{210}Pb rate = 22 mg/cm^2/yr

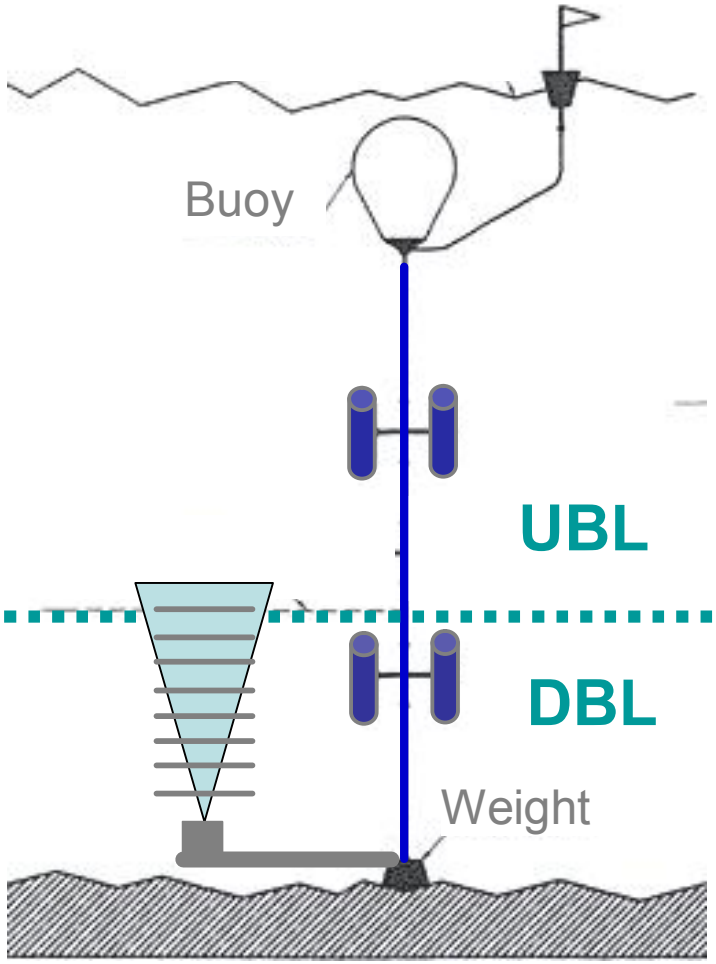
Downward Sedimentation

Selenium downward sedimentation rate:

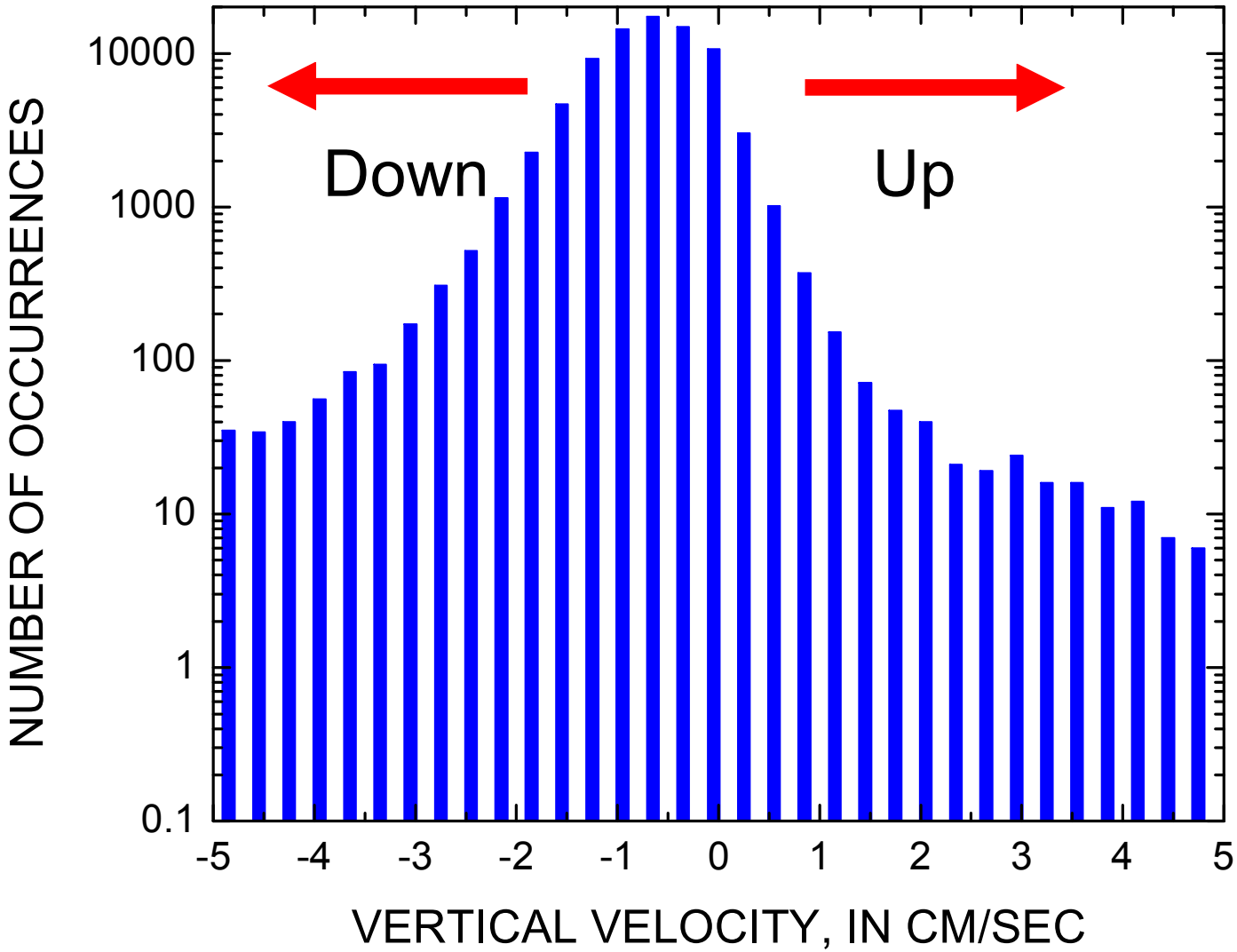
Waiting for Se concentrations from sediment traps (LET and UU labs)

Downward Sedimentation

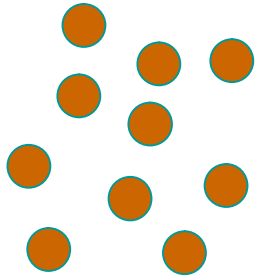




Downward Sedimentation

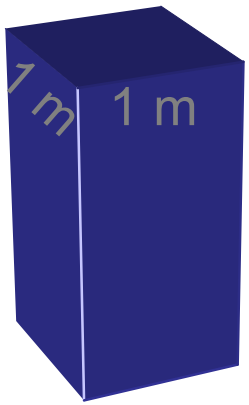


Downward Sedimentation



Particulate Se ($Se_{(part)}$) concentration in mg/m^3 → $Se_{(total)} - Se_{(dissolved)}$

Mean particle velocity in m/min → $V_{(down)}$ (ADCP)



$(Se_{(part)}$, in $mg/0.001m^3) * (V_{(down)}$, in m/min) = $Se_{(flux)}$ $mg/m^2/min$

Deep Brine Layer

Downward Sedimentation

Month	Depth	$Se_{(tot)}$	$Se_{(dis)}$	$Se_{(part)}$
MAY	6.5 m	0.642	0.409	0.233
JUL	7.0 m	0.411	0.248	0.163
SEP	6.5 m	0.526	0.431	0.095

Concentration in ug/L

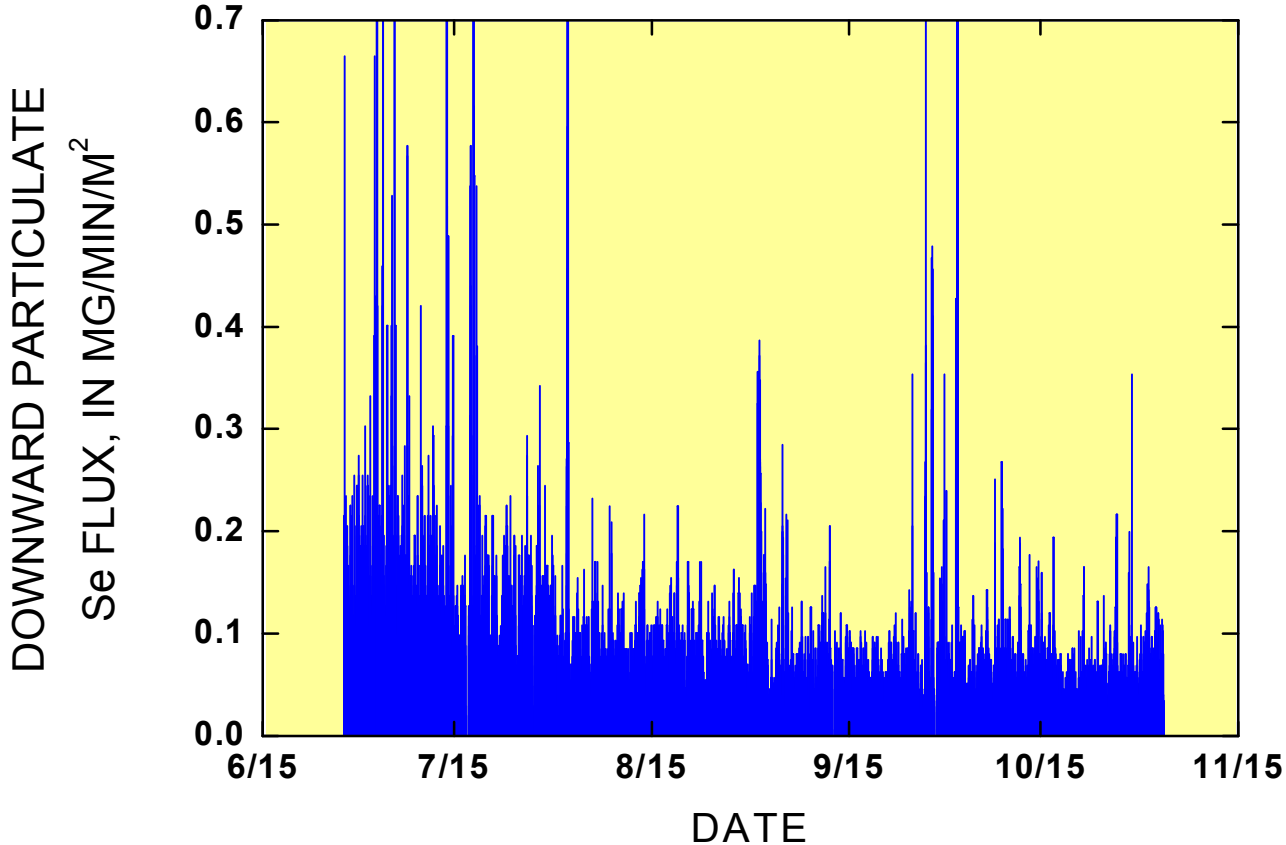
Median Se flux rate

= 0.01 mg/cm^2-day

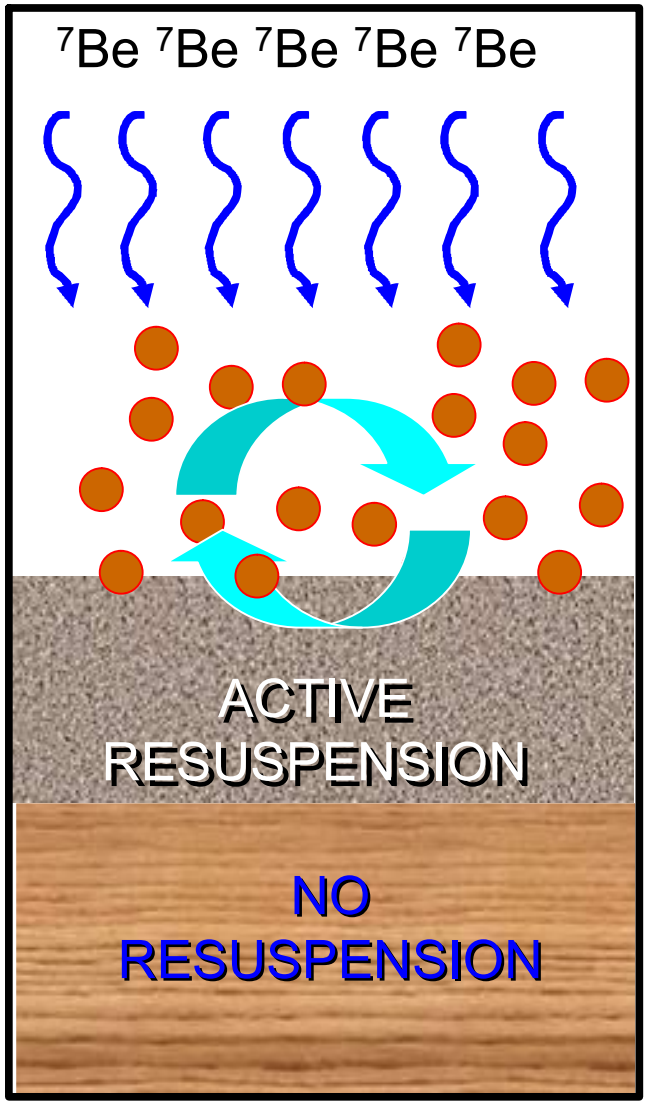
= 1.84E5 kg/day

High!

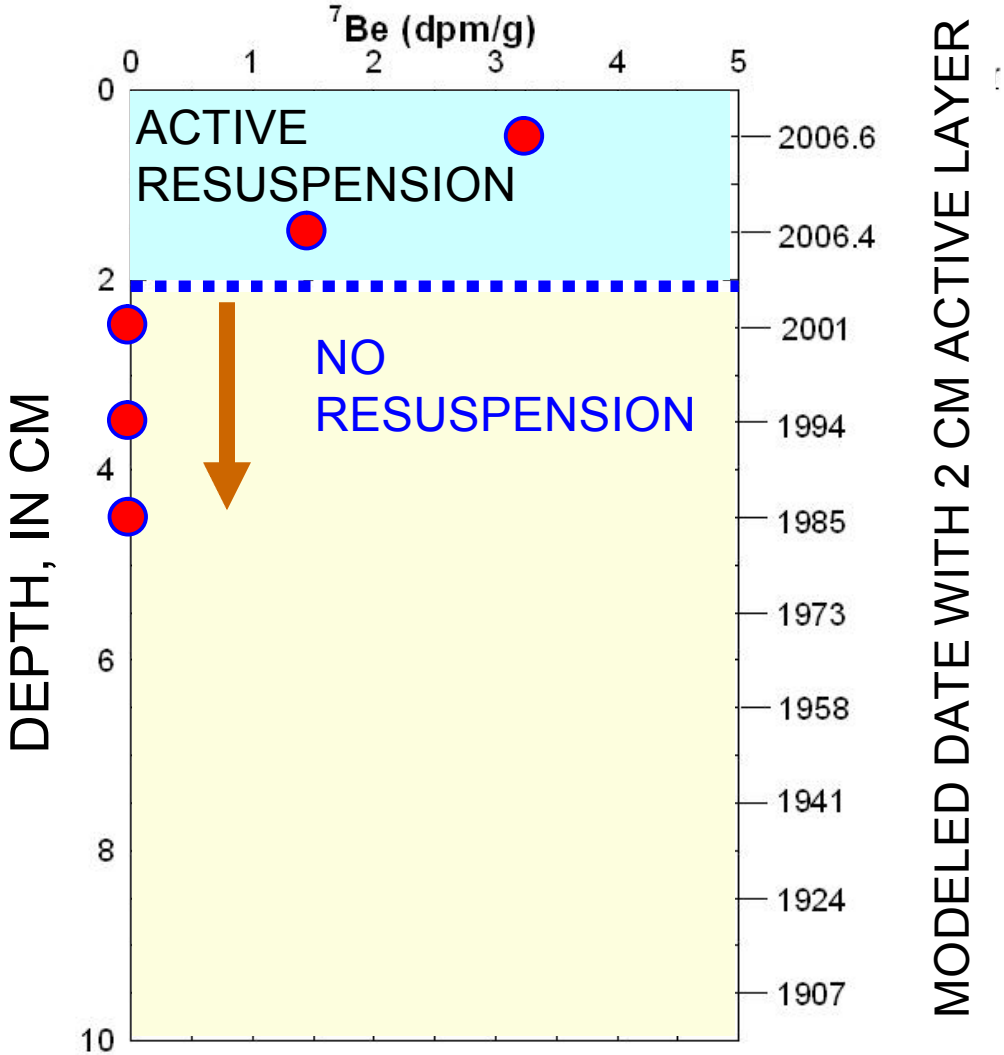
Re-suspension?



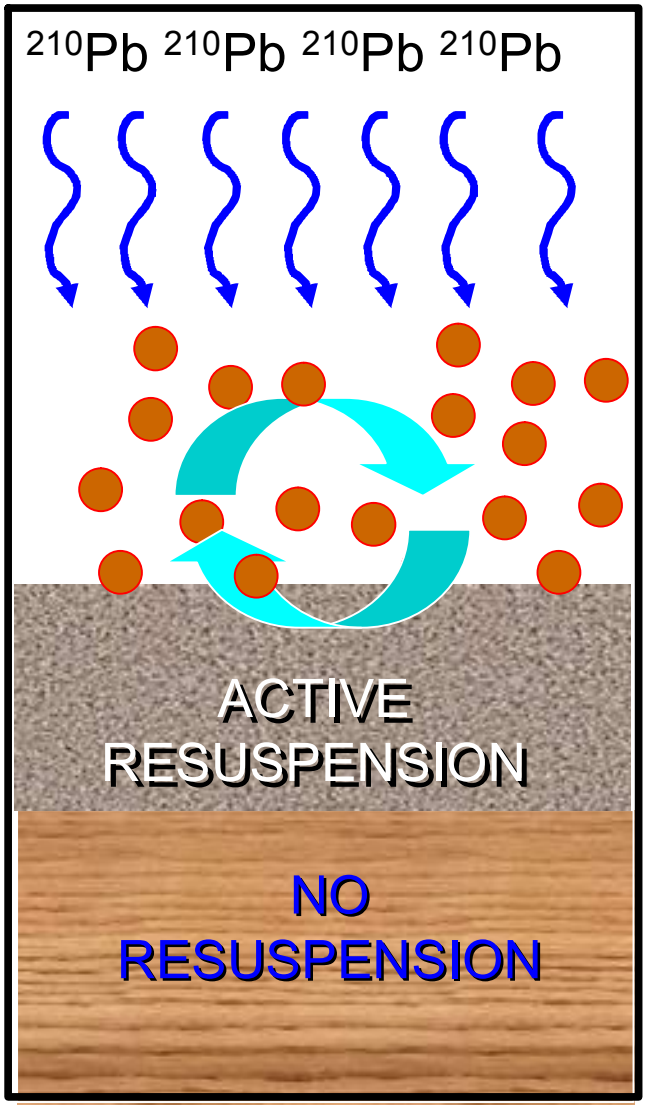
Sediment Re-suspension

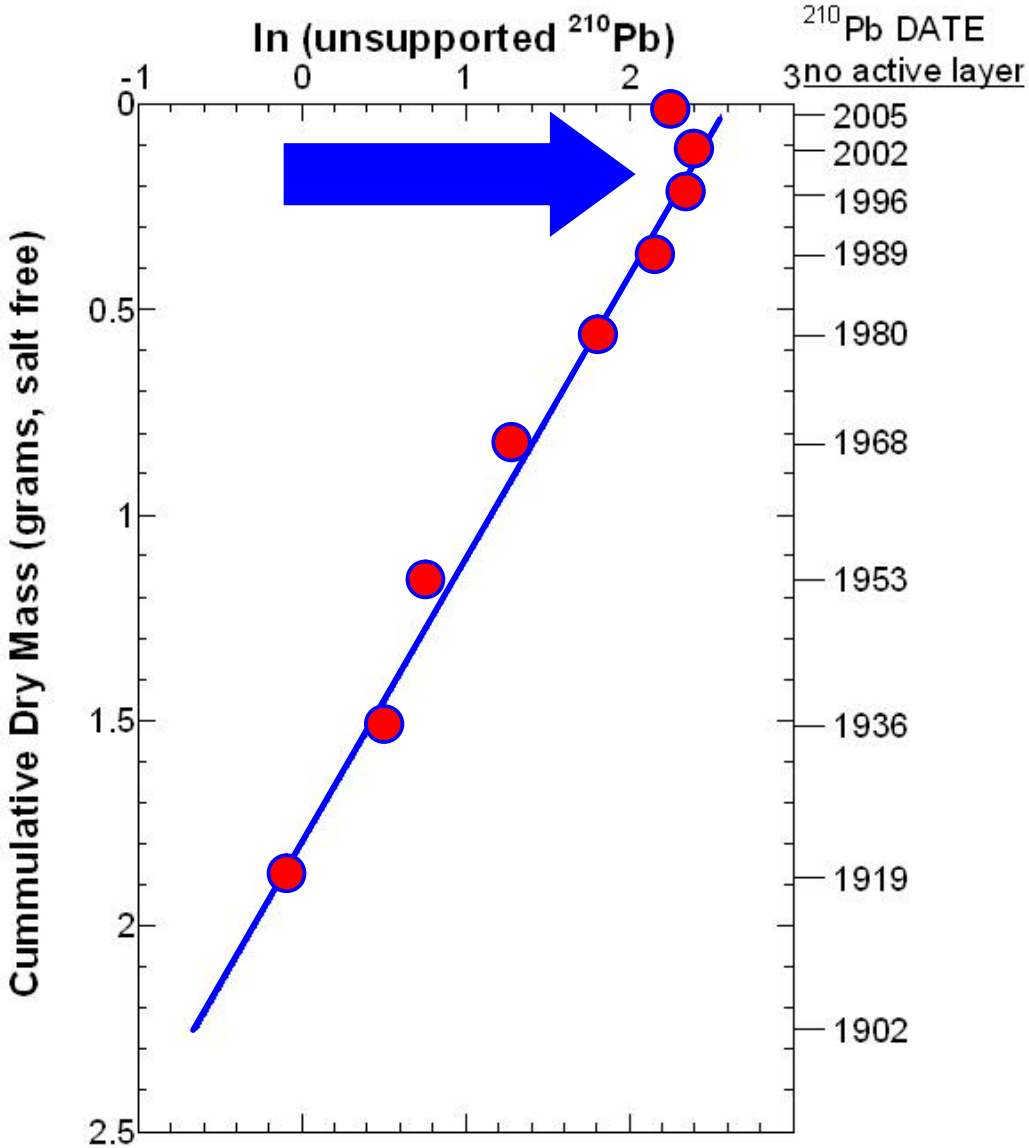


^{7}Be half life = 53 days

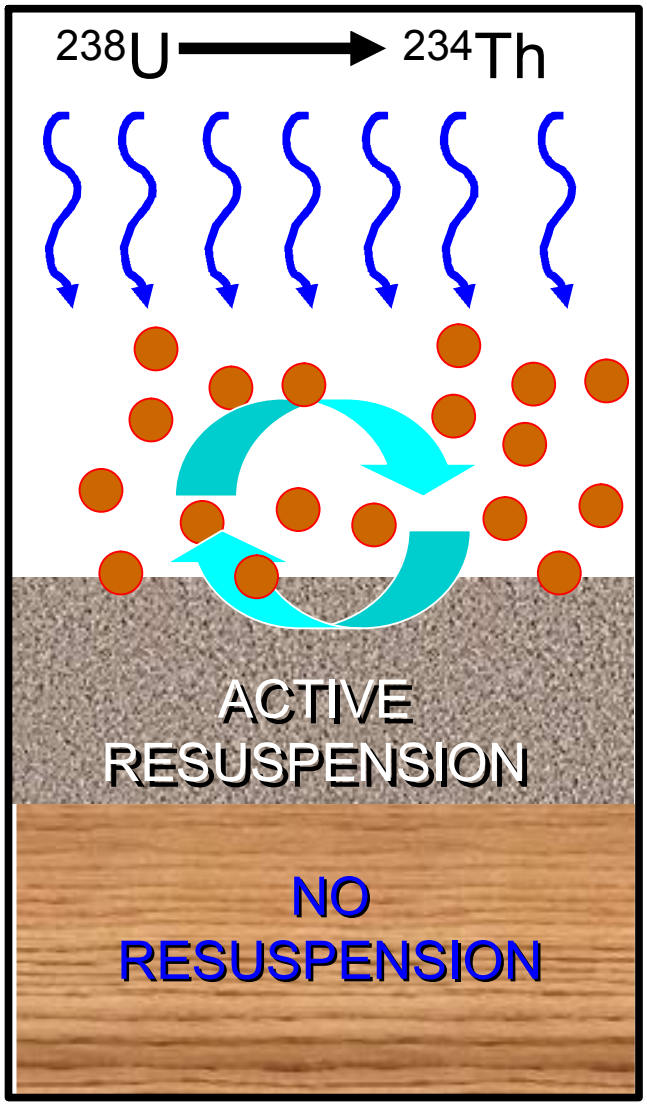


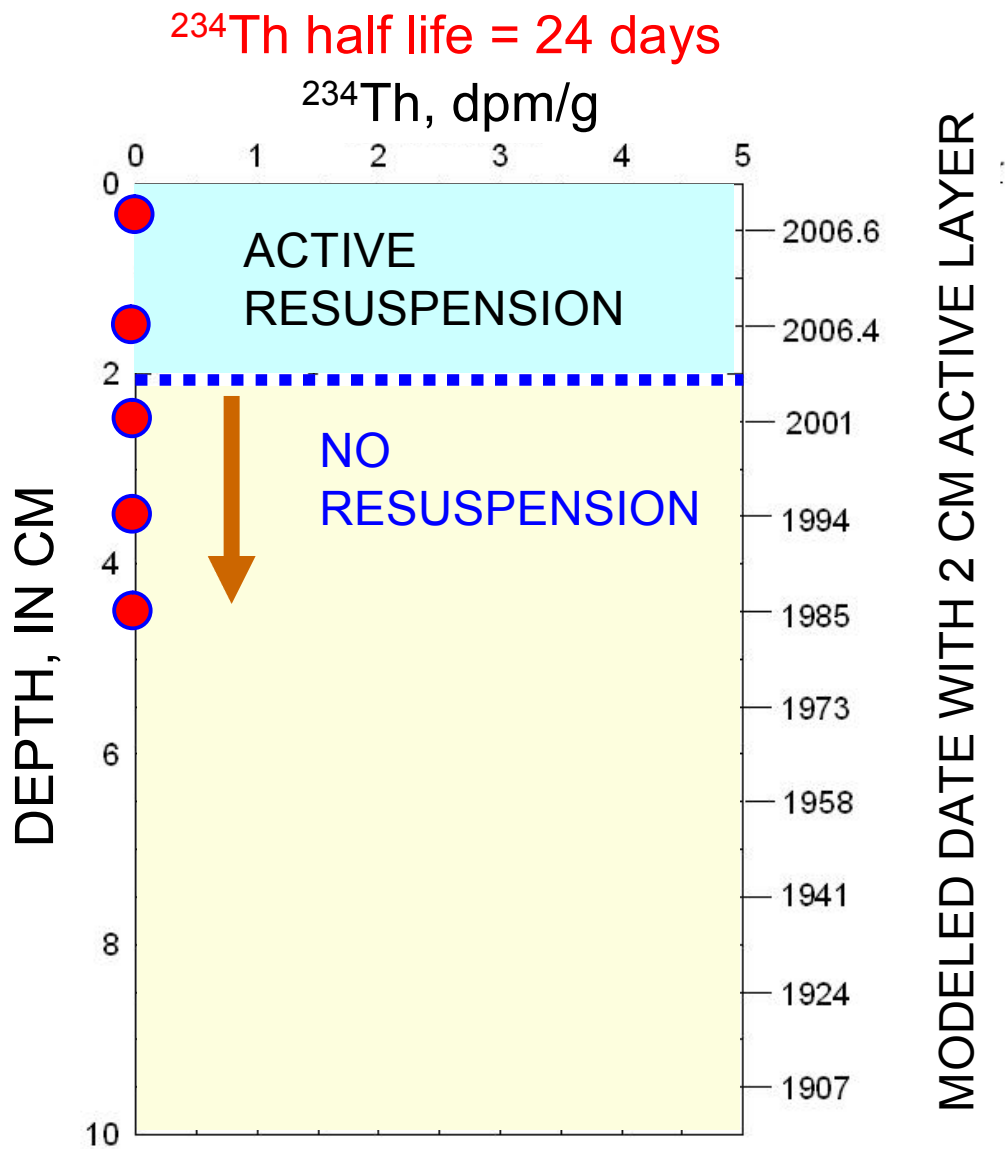
Sediment Re-suspension



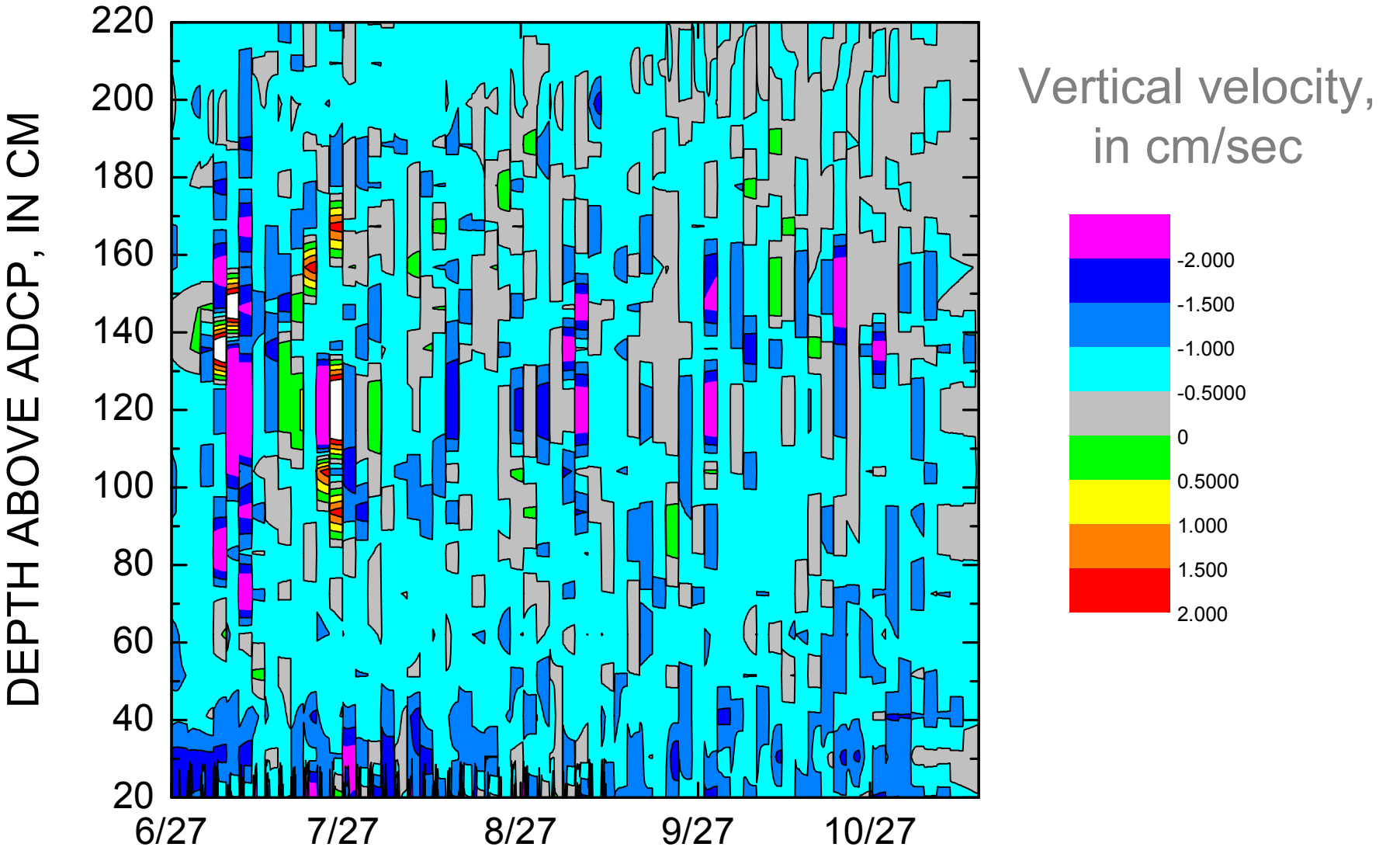


Sediment Re-suspension



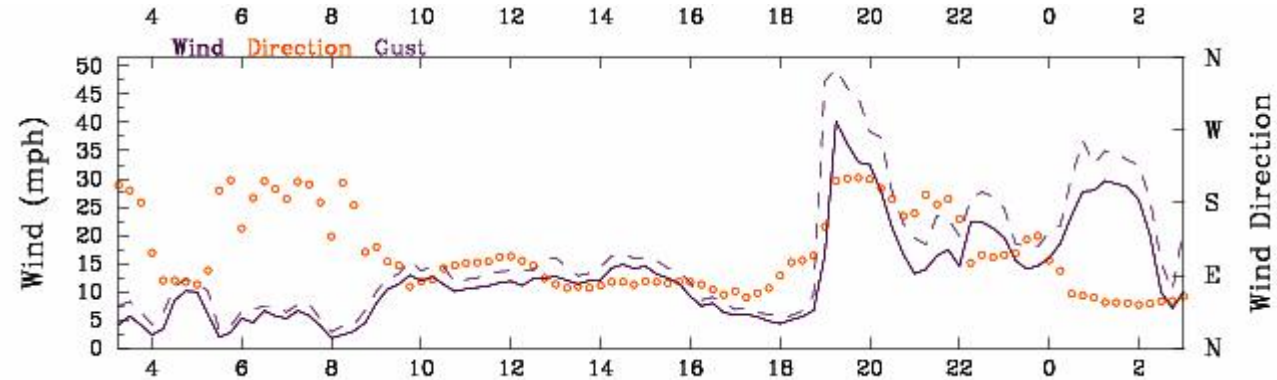


Sediment Re-suspension

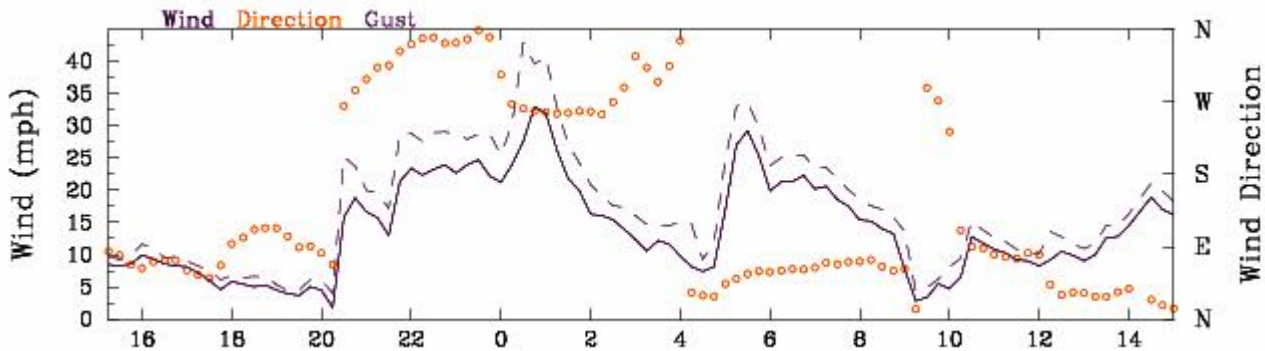


Sediment Re-suspension

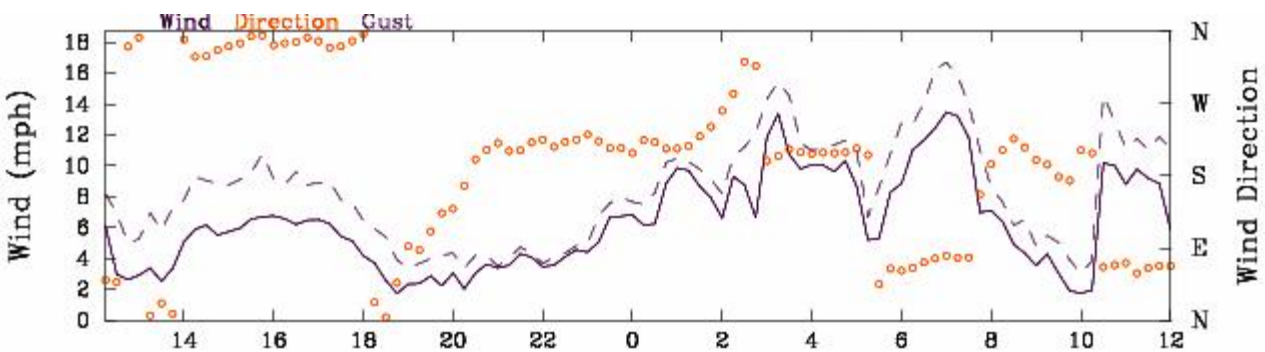
Hat Island Station



7/20 @ 0300

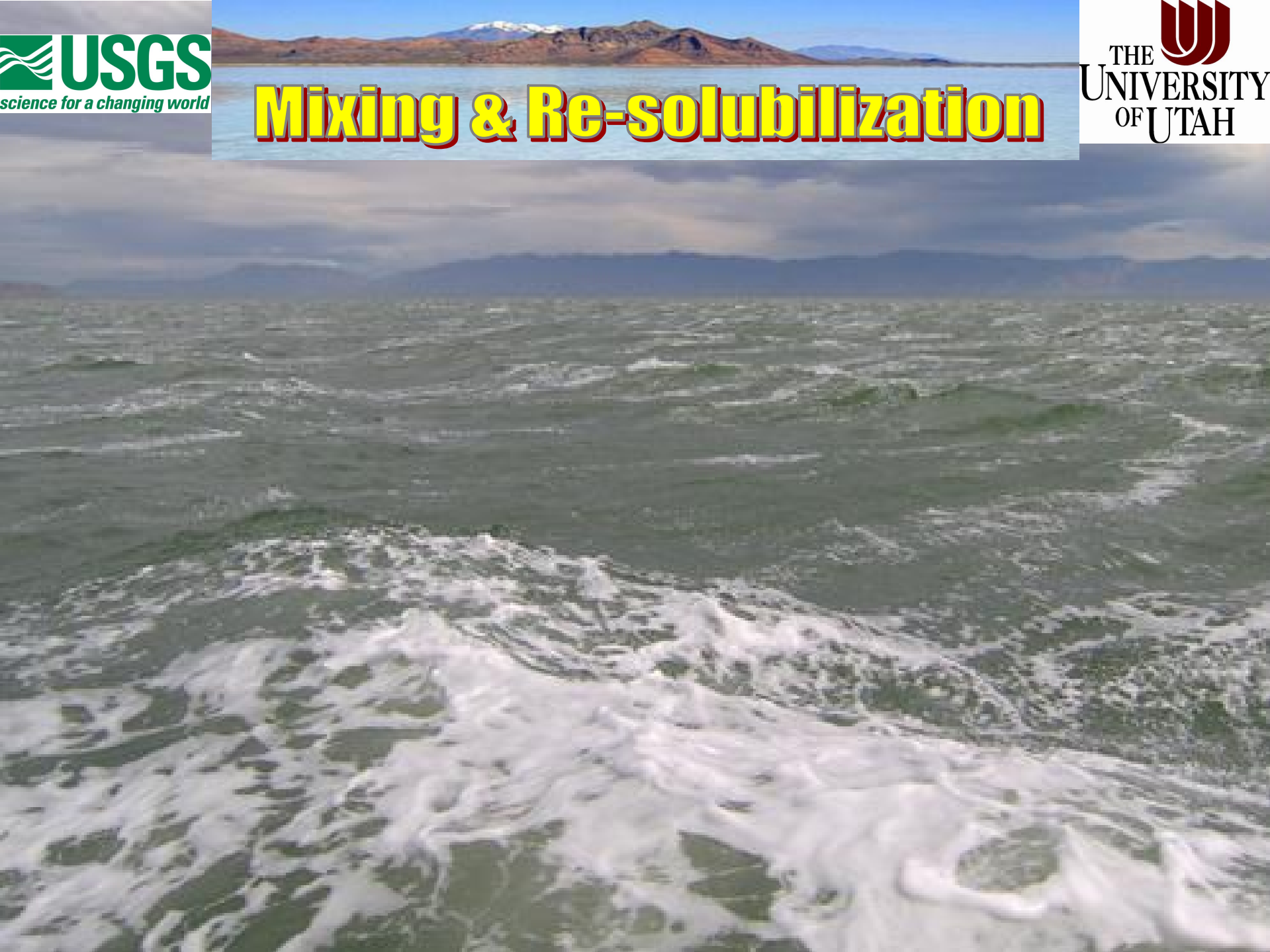


7/24 @ 1500



10/09 @ 1200

Mixing & Re-solubilization



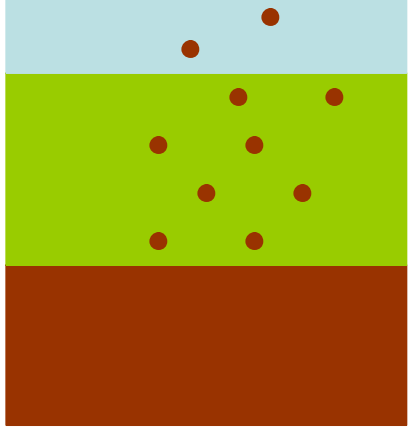
Mixing & Re-solubilization

Quiescent conditions

Bottom sediment in contact with deep brine layer

Mixing & re-solubilization

Re-suspension of bottom sediment into shallow layer

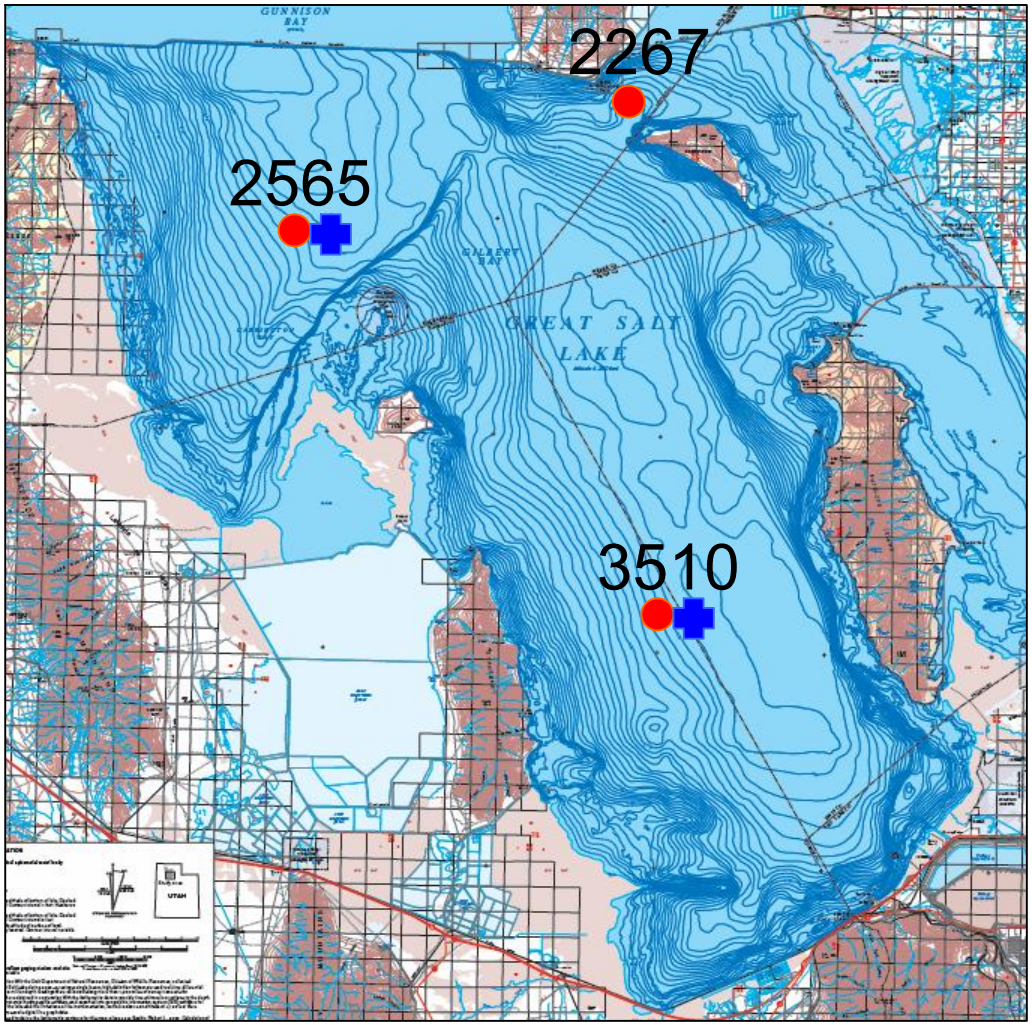


Re-solubilization

Displacement of deep brine layer

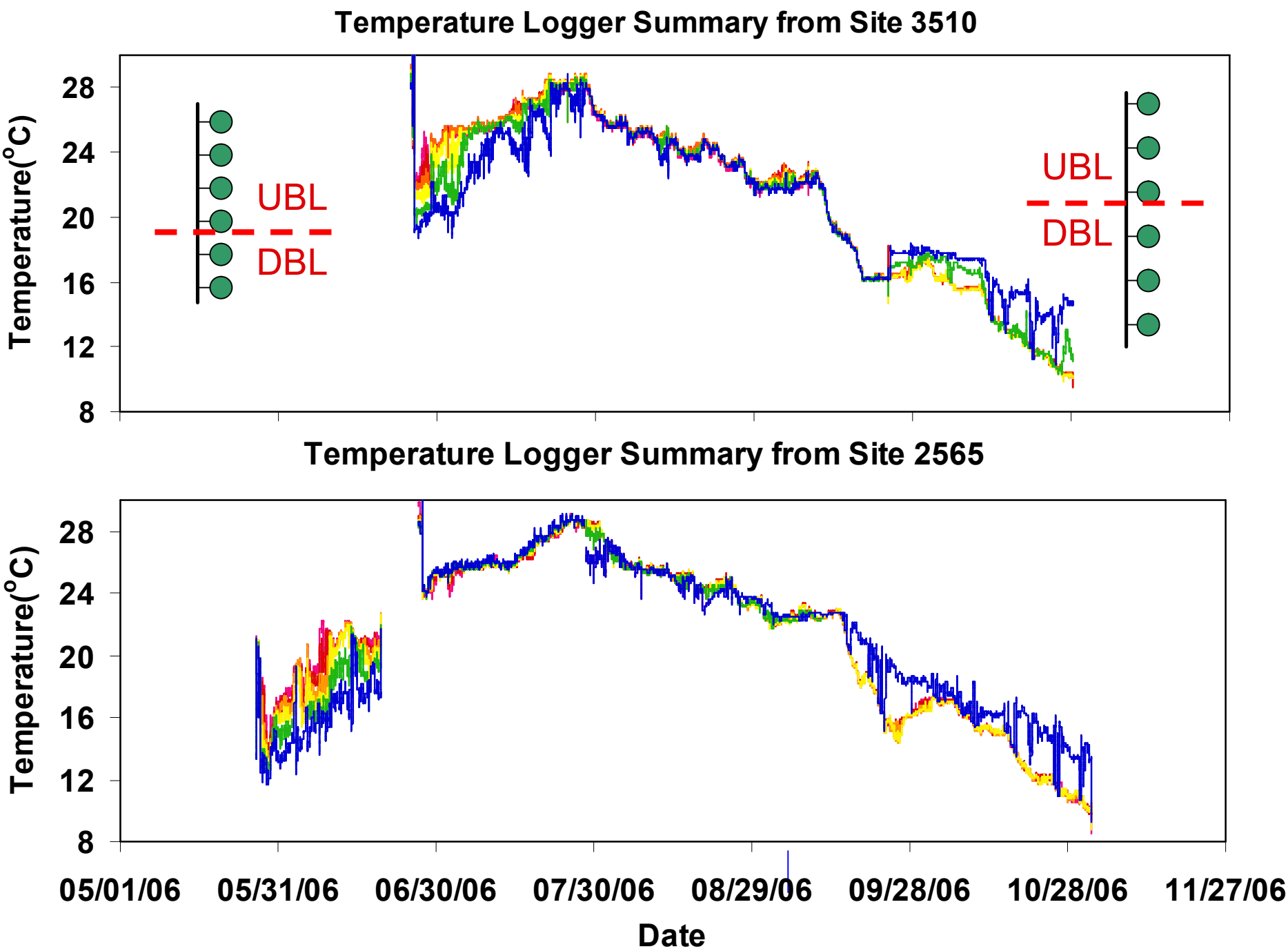
Bottom sediment in contact with shallow brine layer

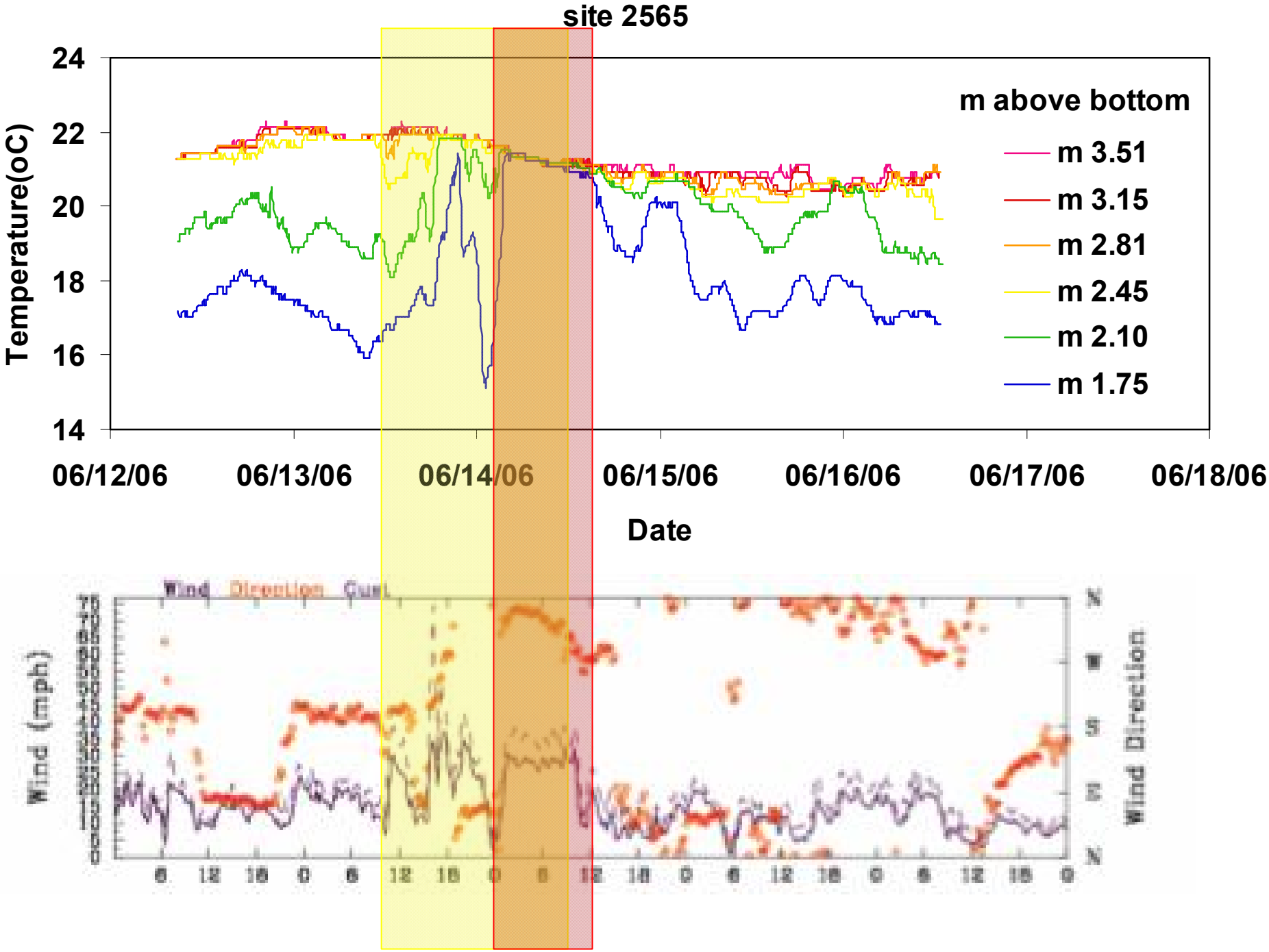
Mixing & Re-solubilization

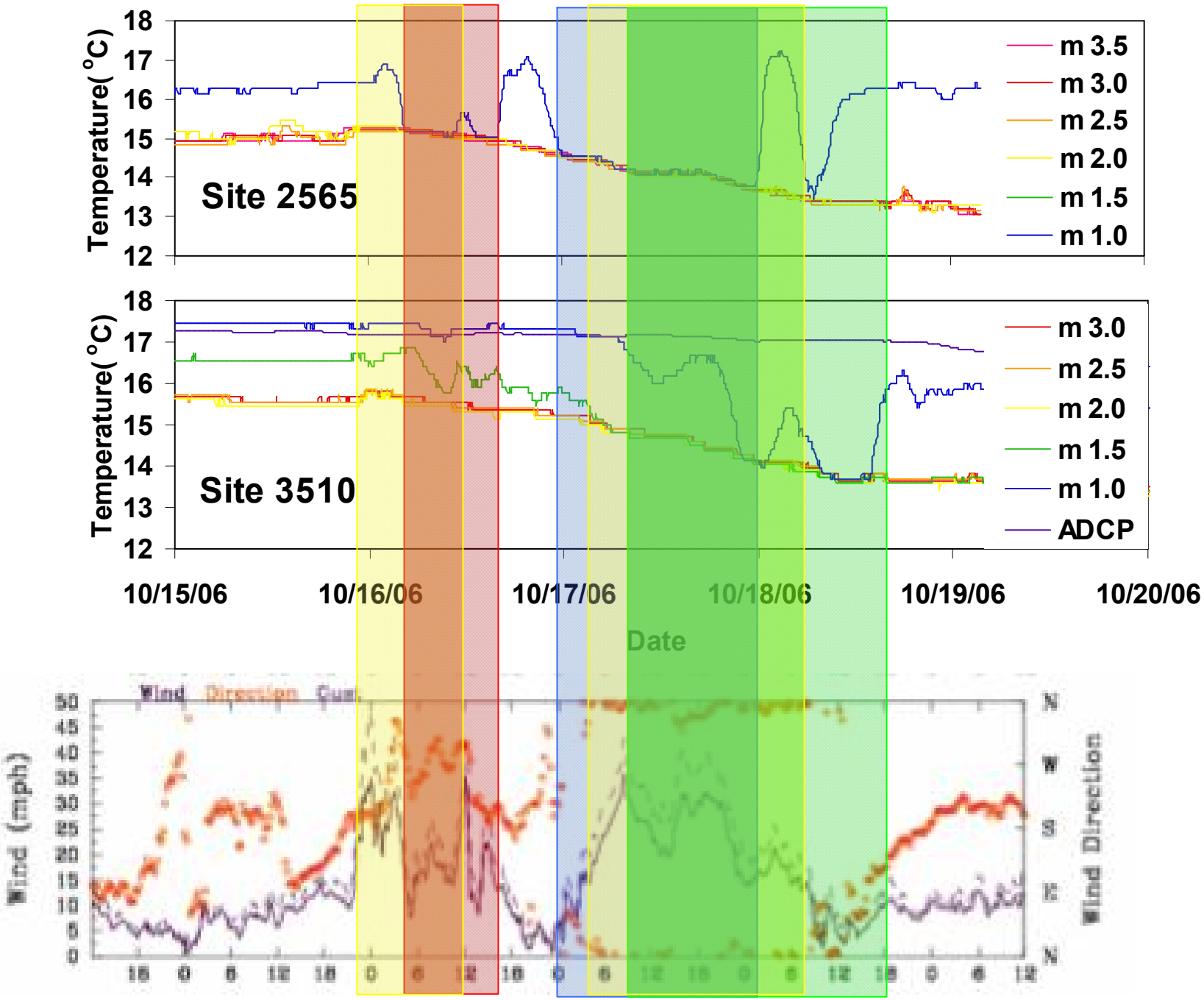


Sample Locations

- Sediment Trap
- Thermistor String


Temperature Logger Summary from Site 3510
Temperature(°C)
28
24
20
16
12
8
UBL
DBL
UBL
DBL
Temperature Logger Summary from Site 2565
Temperature(°C)
28
24
20
16
12
8
05/01/06
05/31/06
06/30/06
07/30/06
08/29/06
09/28/06
10/28/06
11/27/06
Date


site 2565
Temperature(oC)
24
22
20
18
16
14
m above bottom
m 3.51
m 3.15
m 2.81
m 2.45
m 2.10
m 1.75
06/12/06
06/13/06
06/14/06
06/15/06
06/16/06
06/17/06
06/18/06
Date
Wind (mph)
Wind Direction
N
W
S
E
N


Temperature(°C)
Site 2565
m 3.5
m 3.0
m 2.5
m 2.0
m 1.5
m 1.0
Site 3510
ADCP
10/15/06
10/16/06
10/17/06
10/18/06
10/19/06
10/20/06
Date
Wind (mph)
Wind Direction

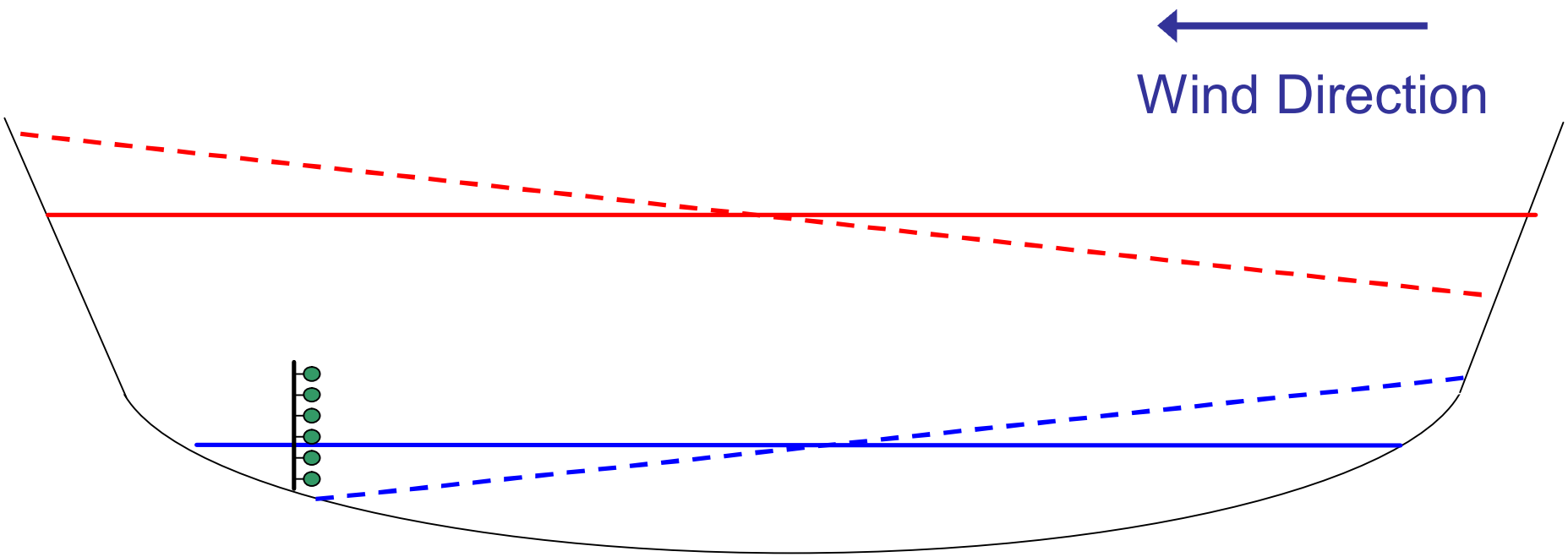
Mechanisms

- Wind Induced Surface Wave
- Seiche or Internal Wave
- Langmuir Circulations
- Thermal Mixing

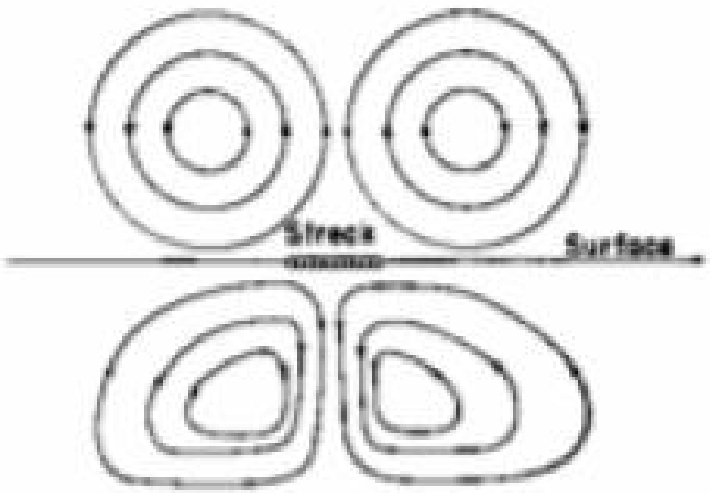
Seiche

Displacement of Water
Responding Oscillations

Set up by Wind and
Atmospheric Pressure



Mixing & Re-solubilization

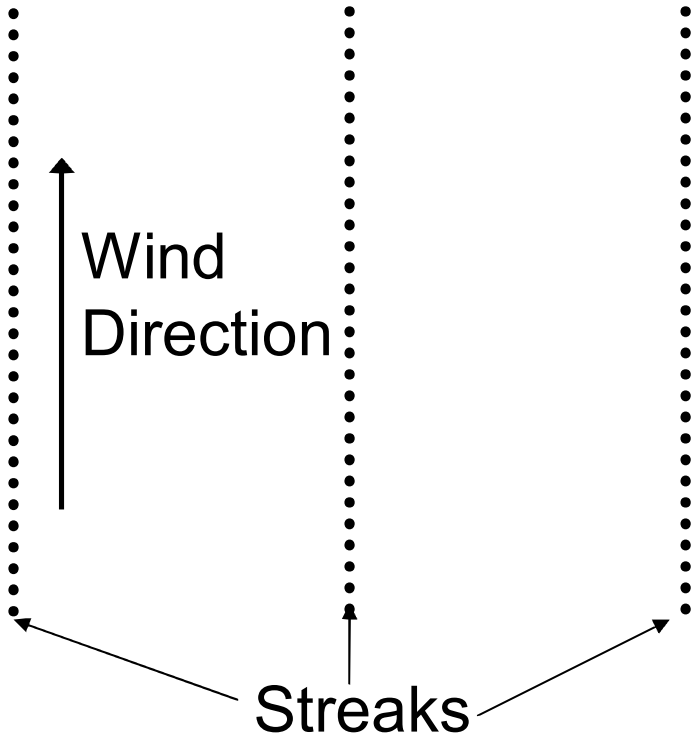


(Scott J. et al., 1969)

Langmuir Circulations

Helical Flow

Circulation Cells at Regular Intervals



Maximum Mixing Depth

6 to 8 m

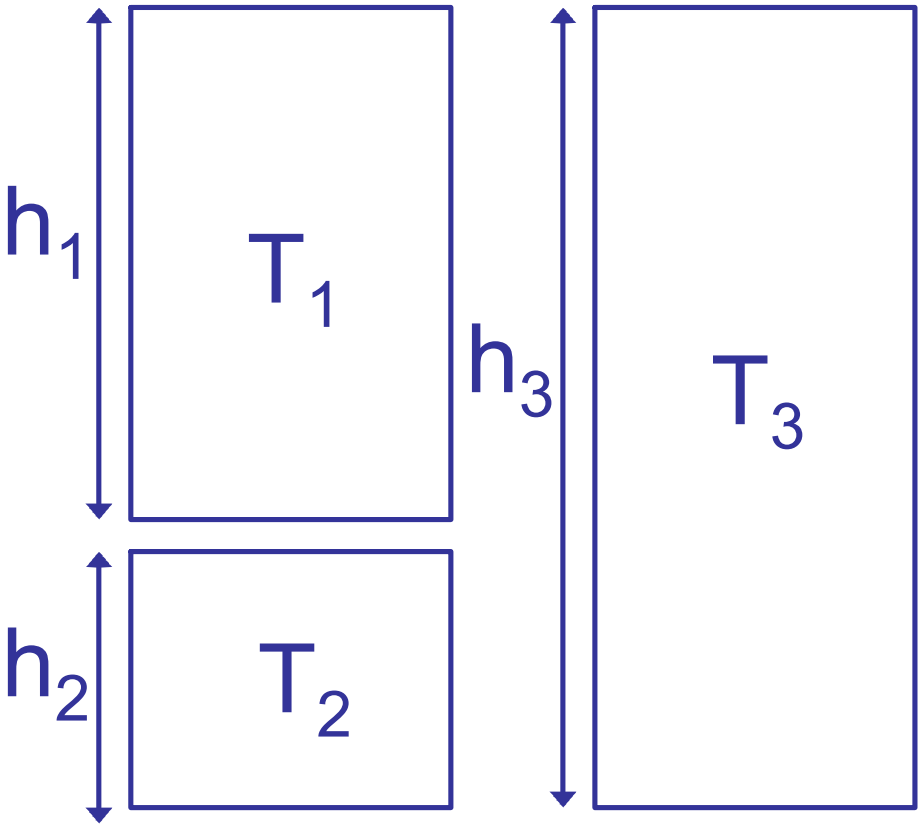
at Lake George, New York

(Scott J. et al., 1969)

Wind Velocities between 2-7 m/s

(Wetzel, 2001)

Thermal Mixing



$$mc\Delta T = \text{energy}$$

$$m_1 c(T_1 - T_3) = m_2 c(T_3 - T_2)$$

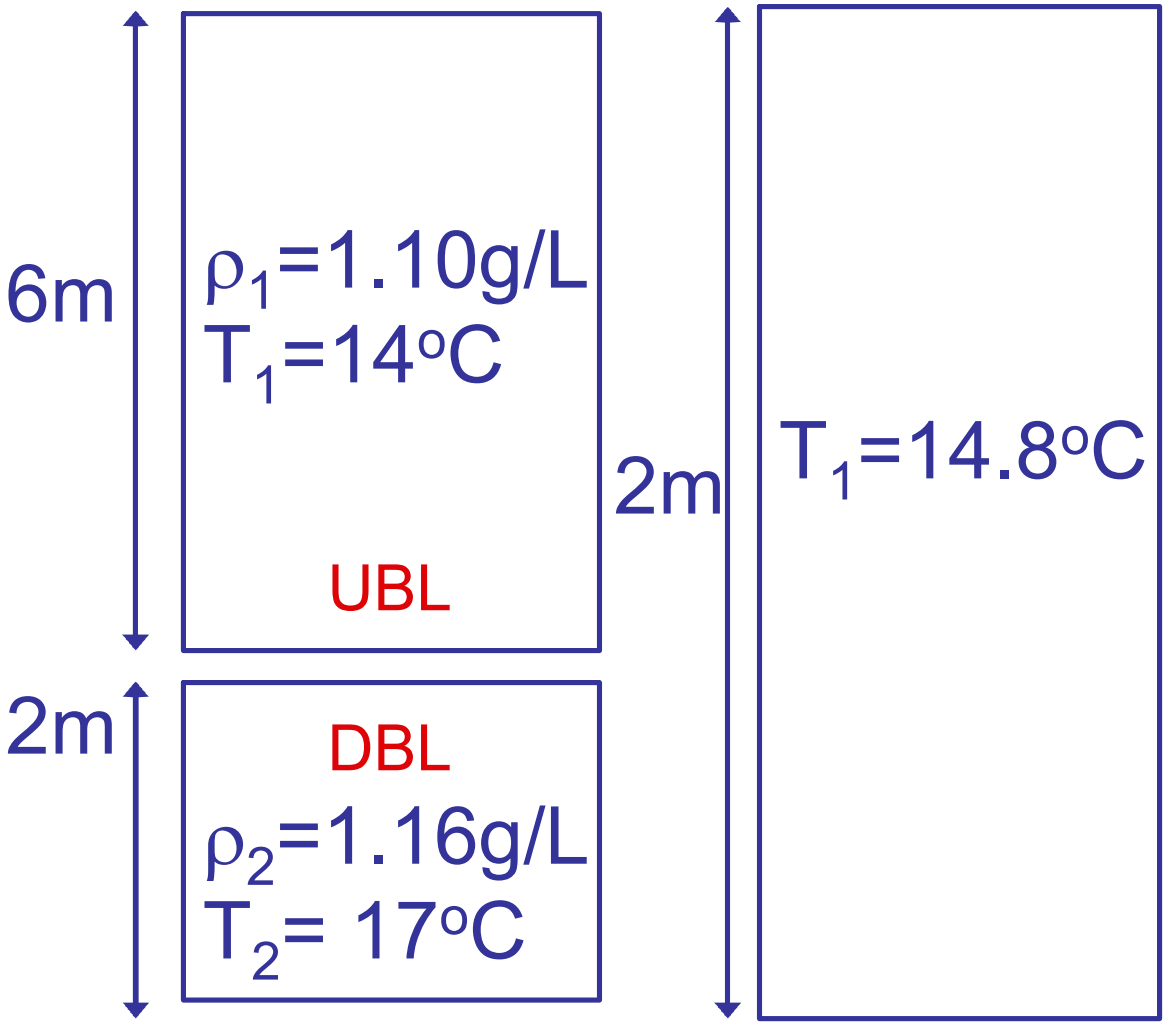
$$m = \rho V = \rho A h$$

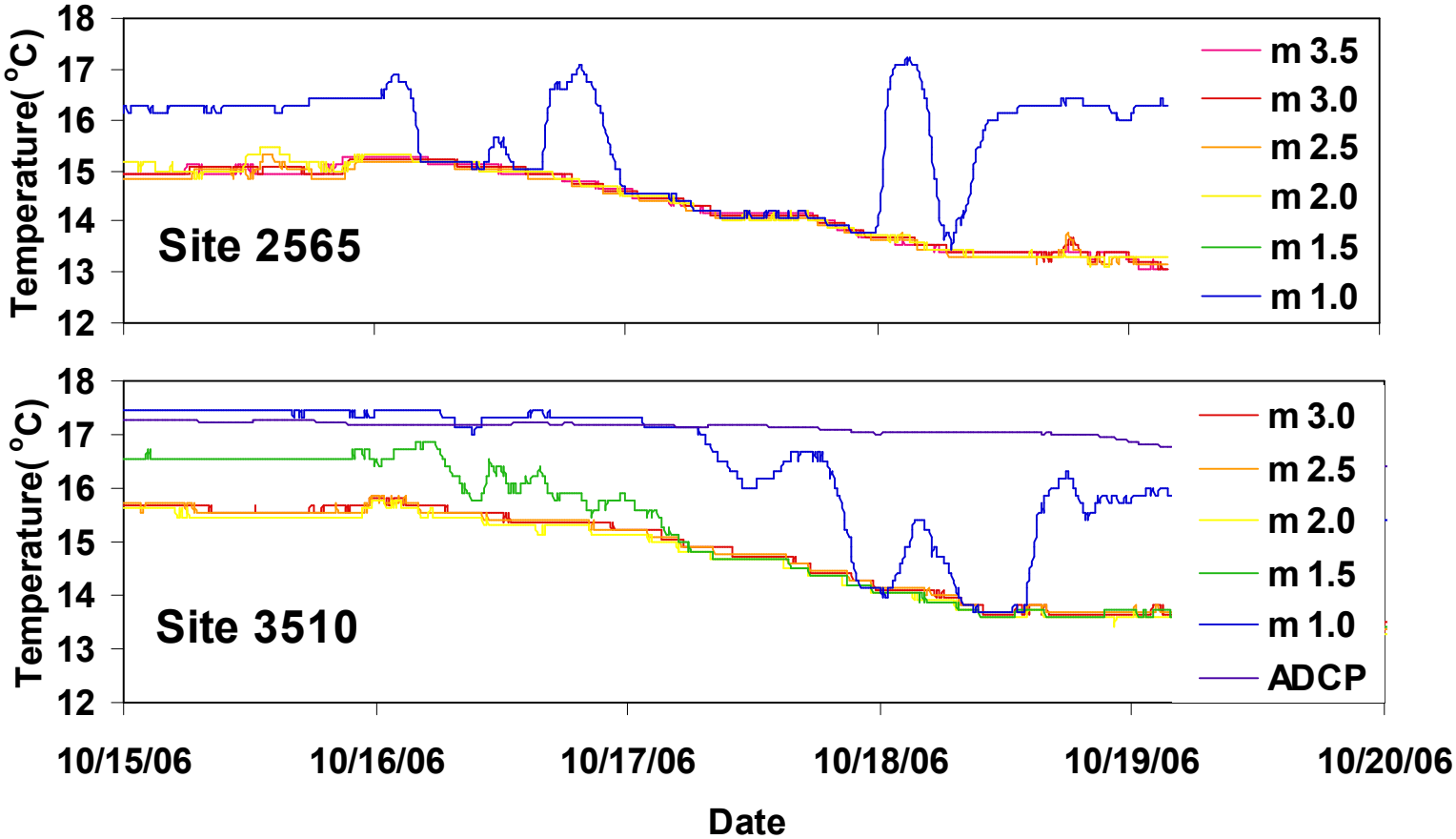
$$\rho_1 h_1 (T_1 - T_3) = \rho_2 h_2 (T_3 - T_2)$$

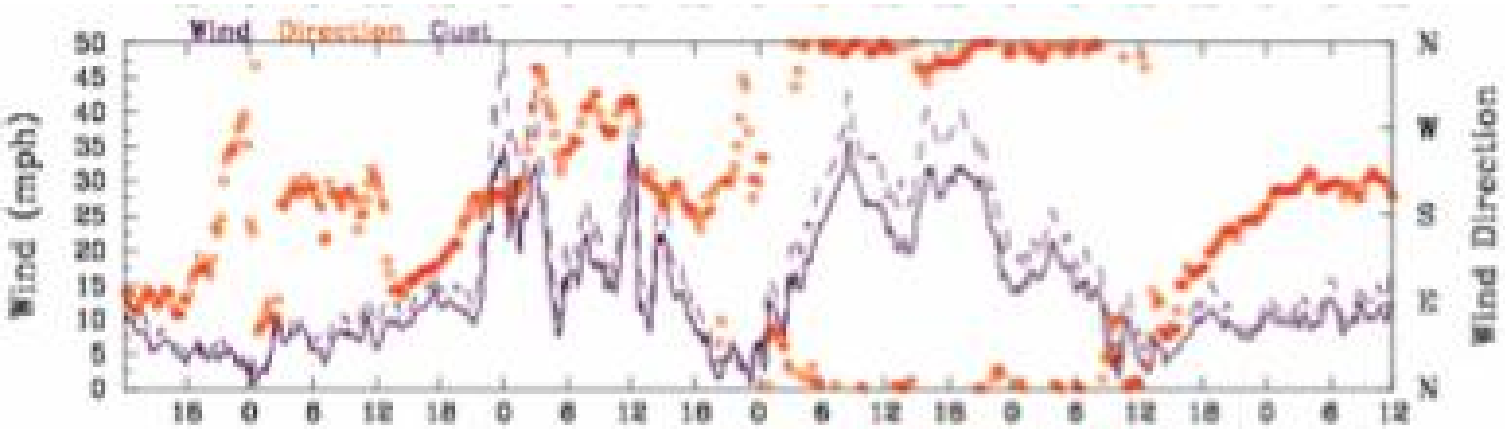
$$\rho_1 h_1 T_1 - \rho_1 h_1 T_3 = \rho_2 h_2 T_3 - \rho_2 h_2 T_2$$

$$T_3 = \frac{\rho_1 h_1 T_1 + \rho_2 h_2 T_2}{\rho_1 h_1 + \rho_2 h_2}$$

Thermal Mixing Example




Temperature(°C)
18
17
16
15
14
13
12
Site 2565
m 3.5
m 3.0
m 2.5
m 2.0
m 1.5
m 1.0
Site 3510
ADCP
10/15/06
10/16/06
10/17/06
10/18/06
10/19/06
10/20/06
Date

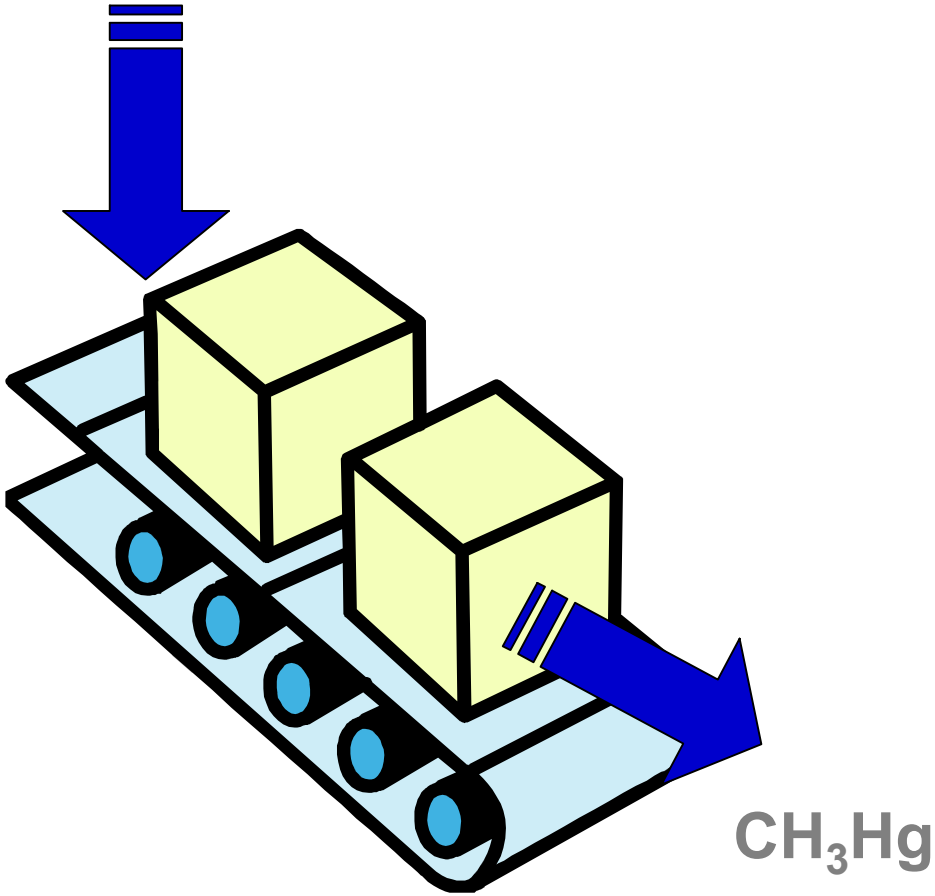

Wind (mph)
Wind Direction
N
W
S
E
N

More Work…

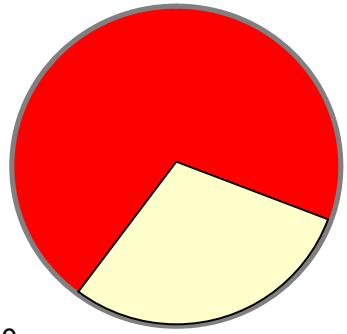
- More temperature data from other times
- Batch equilibration tests with shallow brine water to simulate Se remobilization

Deep Brine Transport of Se

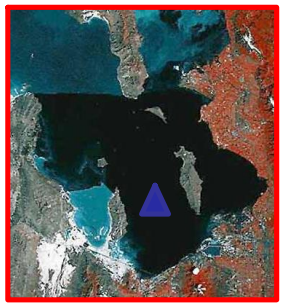
Vertical Se Flux

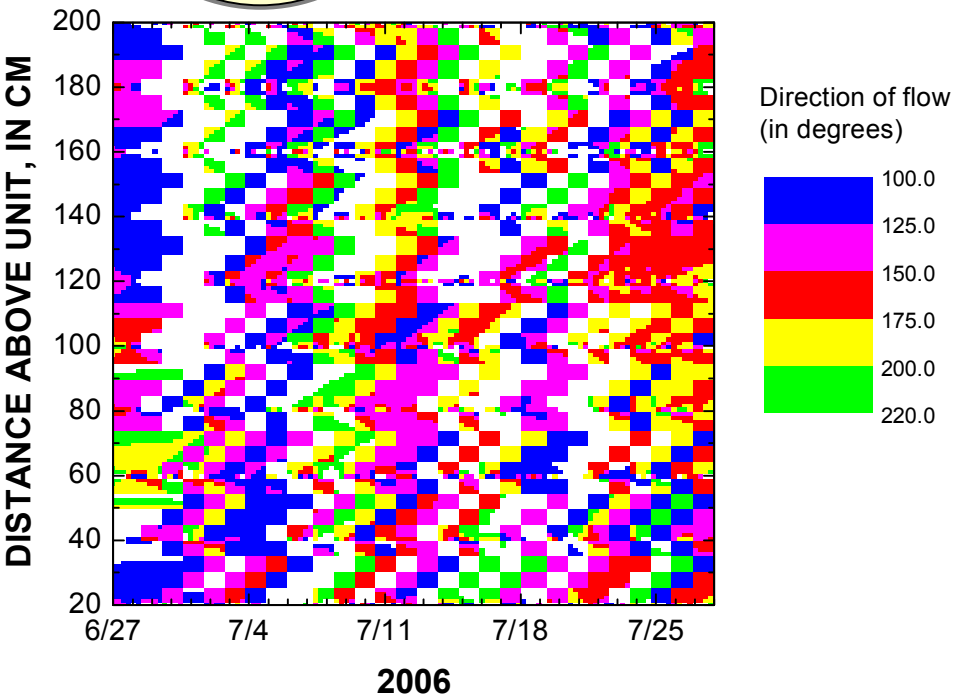


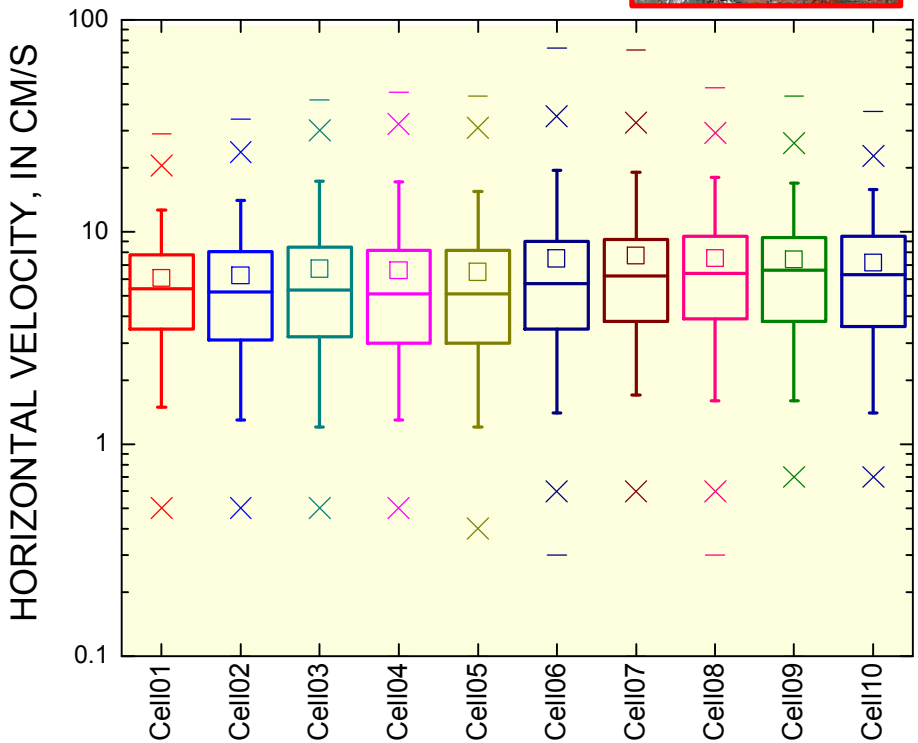
Deep Brine Transport of Se



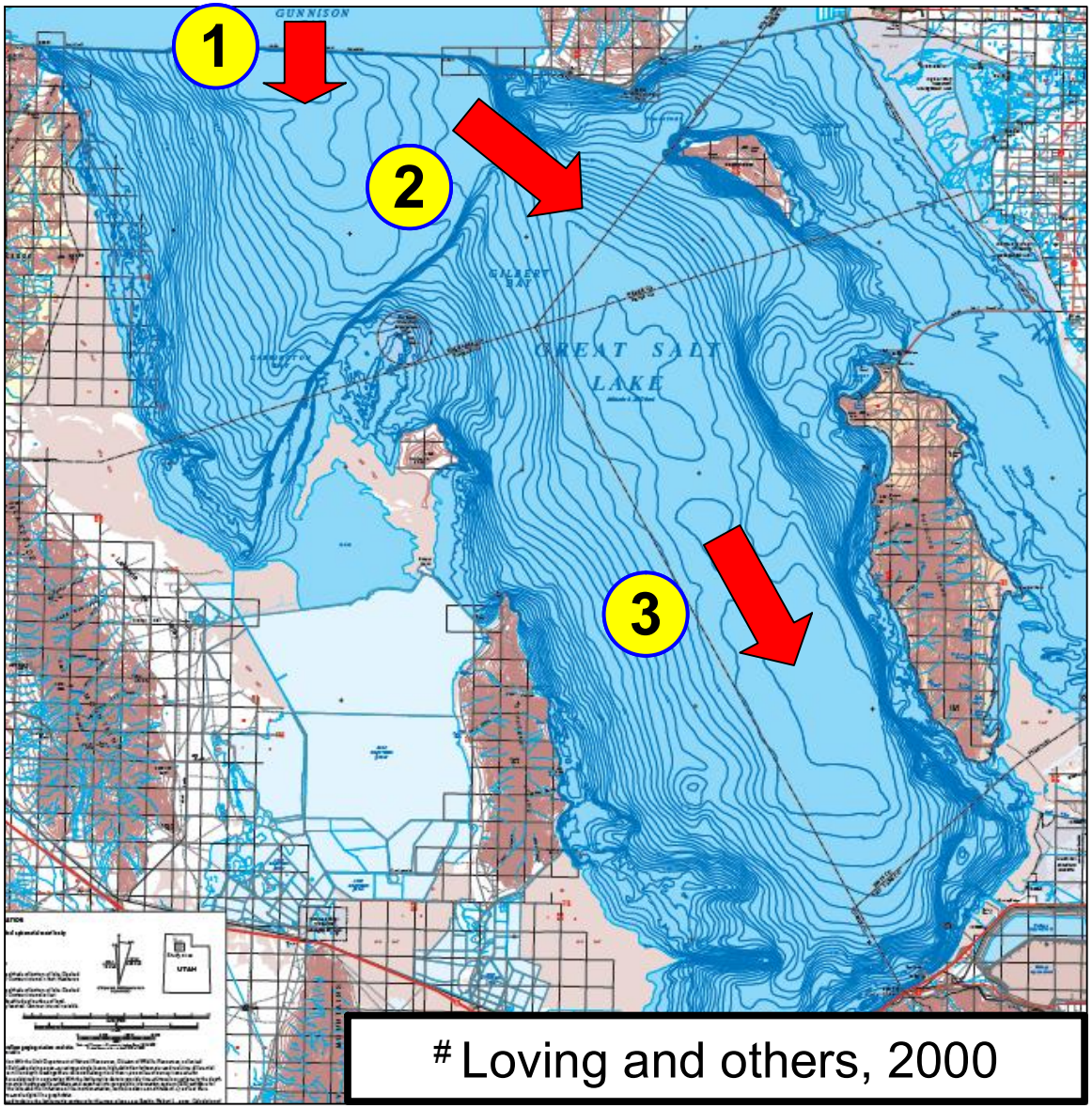
Fixed station flow monitoring







Deep Brine Dynamics



Loving and others, 2000

1 Culverts/Breach + Fill

Culverts/Breach = 5 to 13 m^3/sec

Fill = 1.3 to 197 m^3/sec

Q = 6.3 to 210 m^3/sec

2 DBL Spillway

1.0 m | V = 0.3 m/sec

1,000 m

Q = 300 m^3/sec

3 GSL 3510

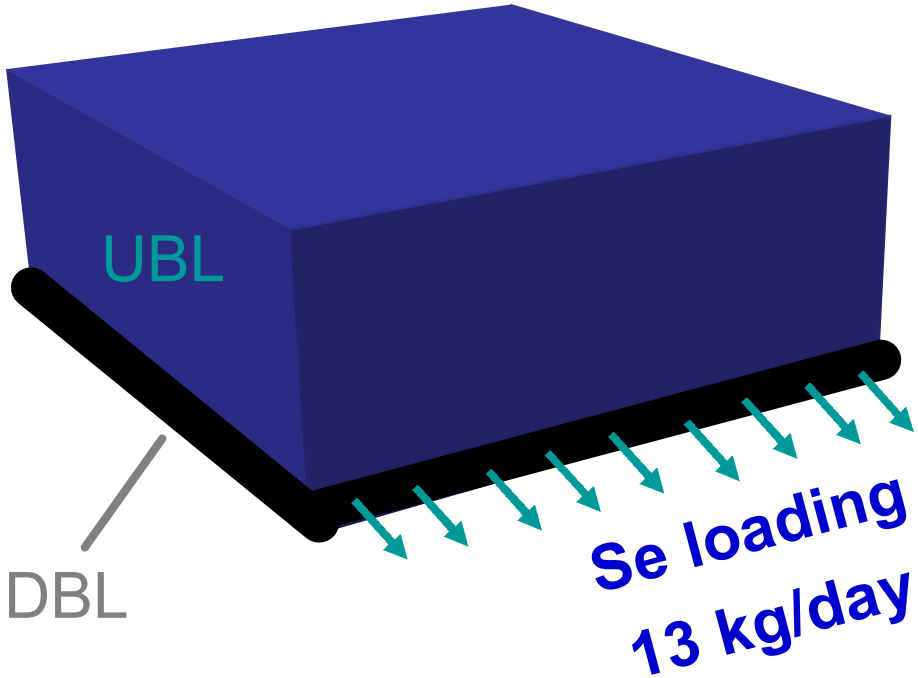
1.5 m | V = 0.05 m/sec

4,500 m

Q = 340 m^3/sec

Deep Brine Dynamics

Date	Se(tot) ug/L	Se(load) kg/day
MAY06	0.716	21
JUL06	0.417	12
SEP06	0.251	7



Assumptions

- DBL "pinches out" south of site 3510
- Velocity of DBL is 0.05 m/sec
- Width of DBL at 3510 is 4,500 m
- Thickness of DBL at site 3510 is 1.5 m

Deep Brine Dynamics

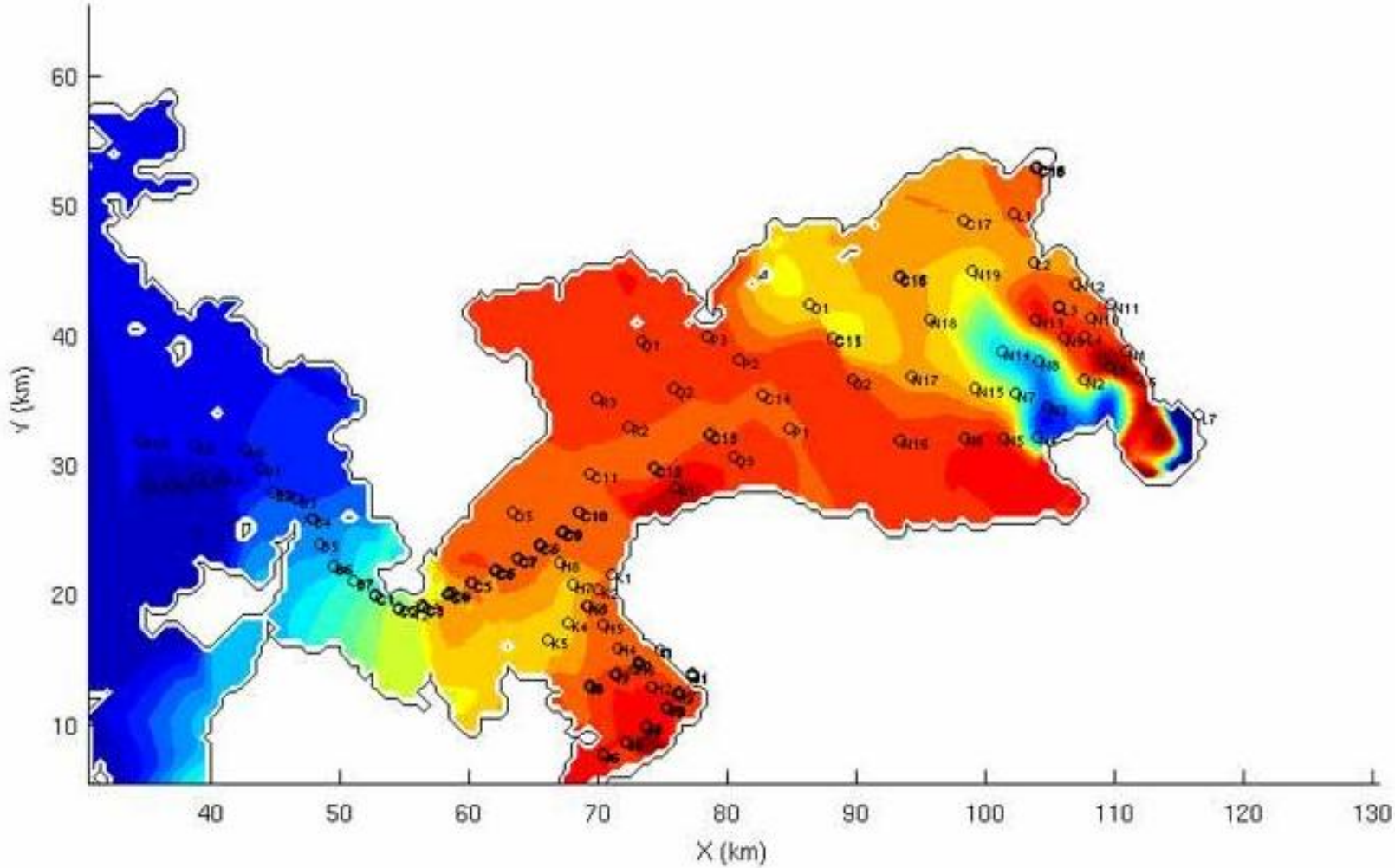


Figure: Map of salinity in Winam Gulf, showing the freshwater input of the major rivers on the eastern margin (in blue), the relatively fresh waters of the main lake to the west (also blue), and the relatively stagnant waters of the Gulf (red) which have higher salinity due to local evaporation. This spatial pattern was also visible in turbidity and algal concentrations, and allowed for the identification of regions influenced by various water quality regimes.

More Work…

Deep brine dynamics

- More ADCP deployment
- Thermistor profiles in N. Arm
- Hydrodynamic model
- Tracer test

Particulate Se

- Particulate size and type via FFF-ICP-MS