Assessment of the influence of sea level rise in the Chesapeake Bay

Part I: Simulation on response in hydrodynamics

Part Ia: by adjusting boundary elevation and salinity

Part 1b: also adjusting water temperature (not yet)

Ping Wang

July 24, 2013

ModWG, QR

Assessment of impact of sea level rise is one of the assessments on the impact of climate change on the Chesapeake Bay ecosystem.

The simulation of response in hydrodynamics to sea level rise is the first step on the assessment of the impact of sea level rise.

Modeling tool: using the current Chesapeaje Bay regulatory model: CH3D-WES.
* Keeps the model structure: Z-grid (5 ft vertical resolution), 56920 cells, boundary near the Bay mouth.

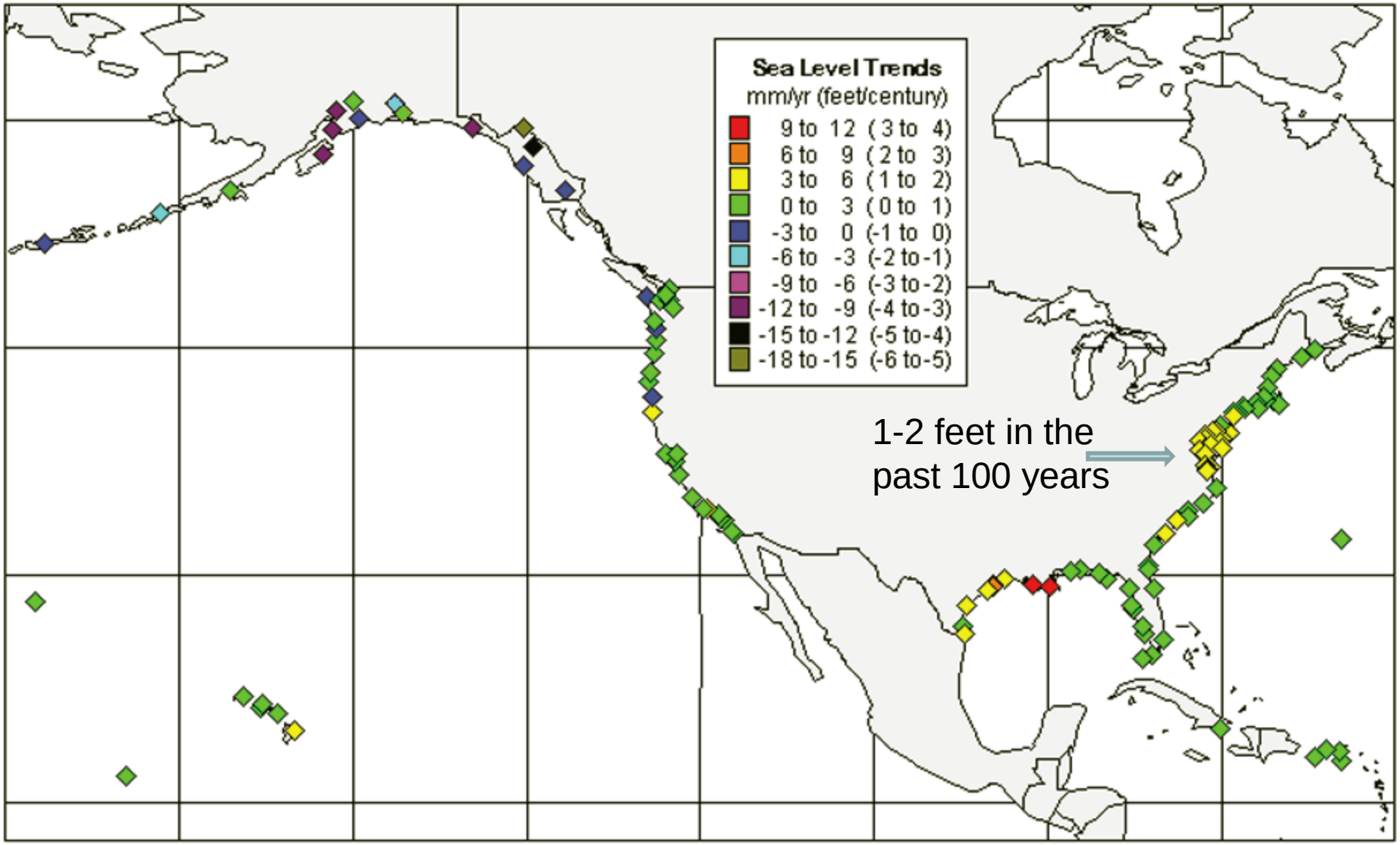
This work is to adjust the boundary condition of water elevation and salinity on CH3D simulation.

1) Estimate of SLR at 2050 – based on literature reviews.

2) Estimate the salinity at the boundary in the SLF scenarios. based on Hong and Shen (2012) and data provided by Dr. Jian Shen of VIMS.

3) Investigate observations and models

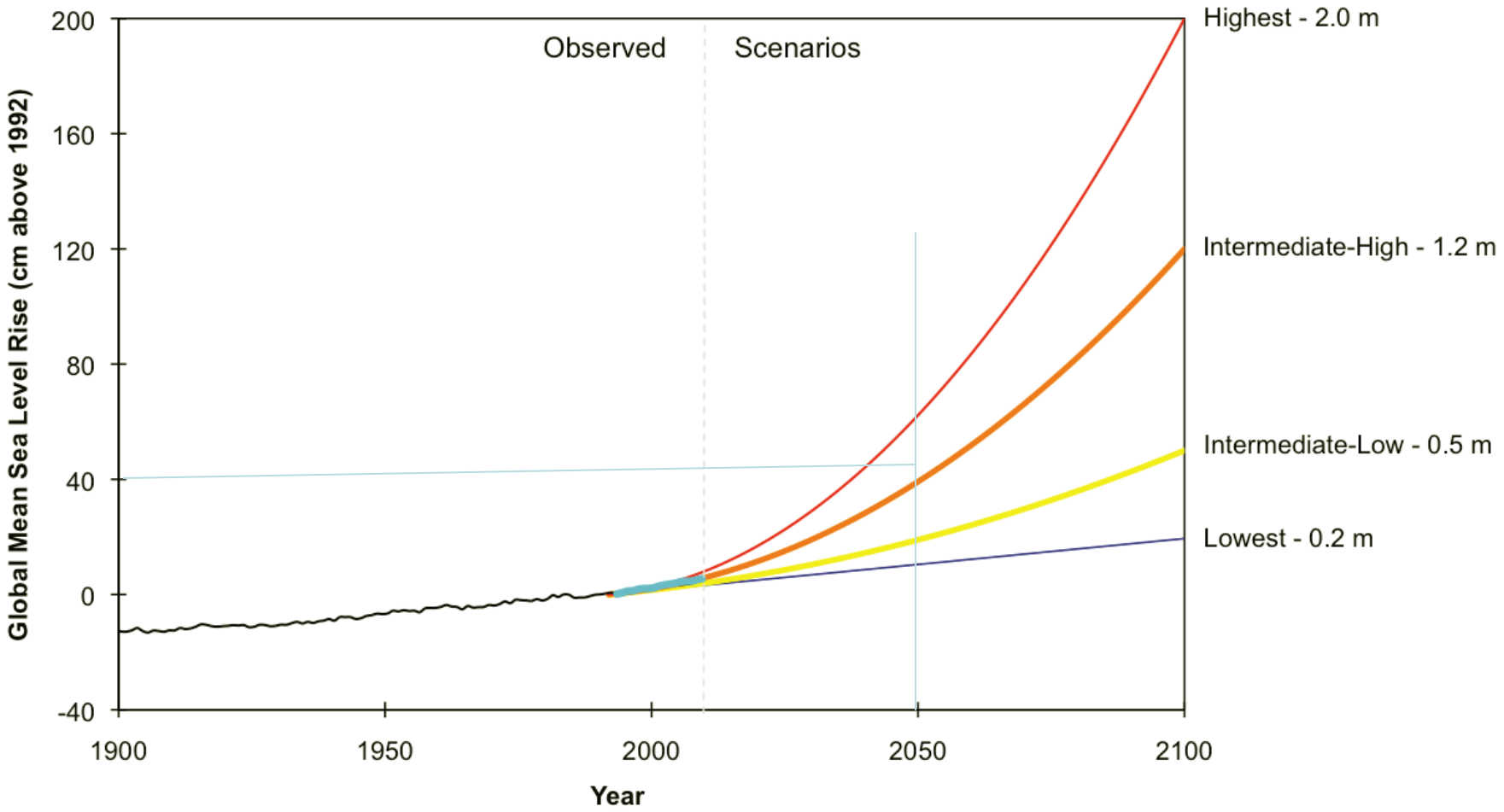
4) CH3D testing run with adjust boundary conditions



Relative Sea Level (RSL) Variations of the United States (1854 to 2006). Derived from 128 National Water Level Observation Network Stations.

NOAA Technical Report OAR CPO-1 (2012)

Global Sea Level Rise Scenarios for the United States
National Climate Assessment



NOAA Technical Report OAR CPO-1 (2012)

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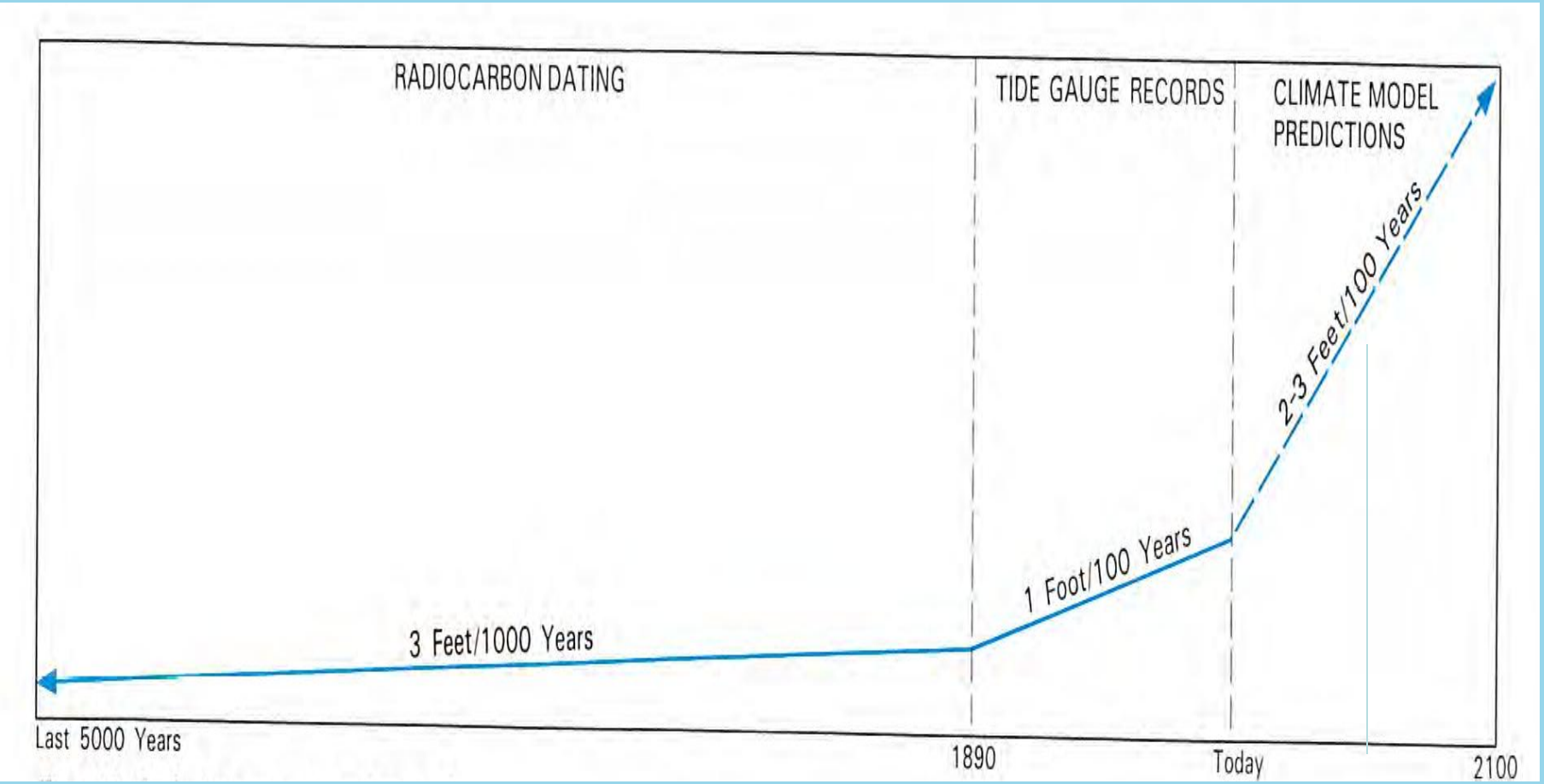


From Leatherman et al. (1997):

Vanishing Lands

Sea Level, Society and Chesapeake Bay

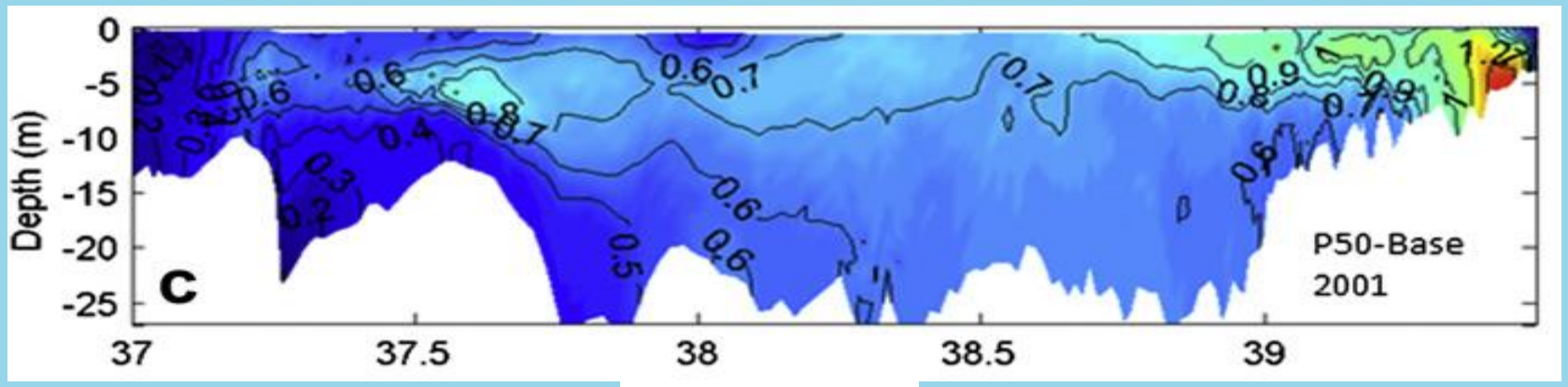
From 2000 to 2050
1-1.5 ft SLR

Impact of Sea Level Rise

- Salt intrusion
- Stratification and pycnocline depths
- Circulation of particles (dissolved & particulate)
- Dissolved oxygen (effect due to change in water temperature and stratification, bio-chemical processes, resident time of nutrient and organics)

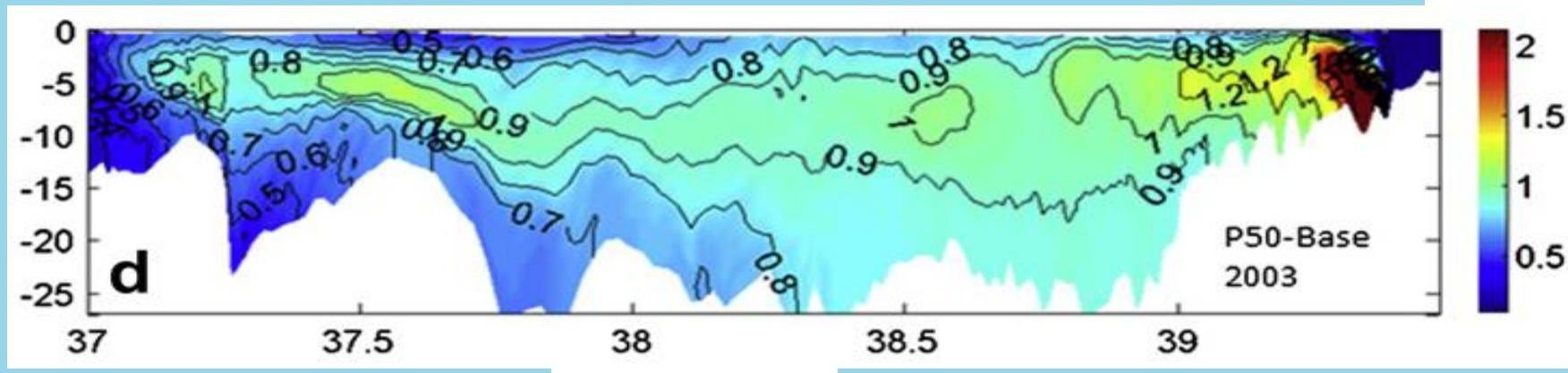
- Wetland loss due to SLR
- Loss of other landuses in the watershed
- Shallow water ecosystem.

Salinity difference between P50 and Base



Latitude

psu



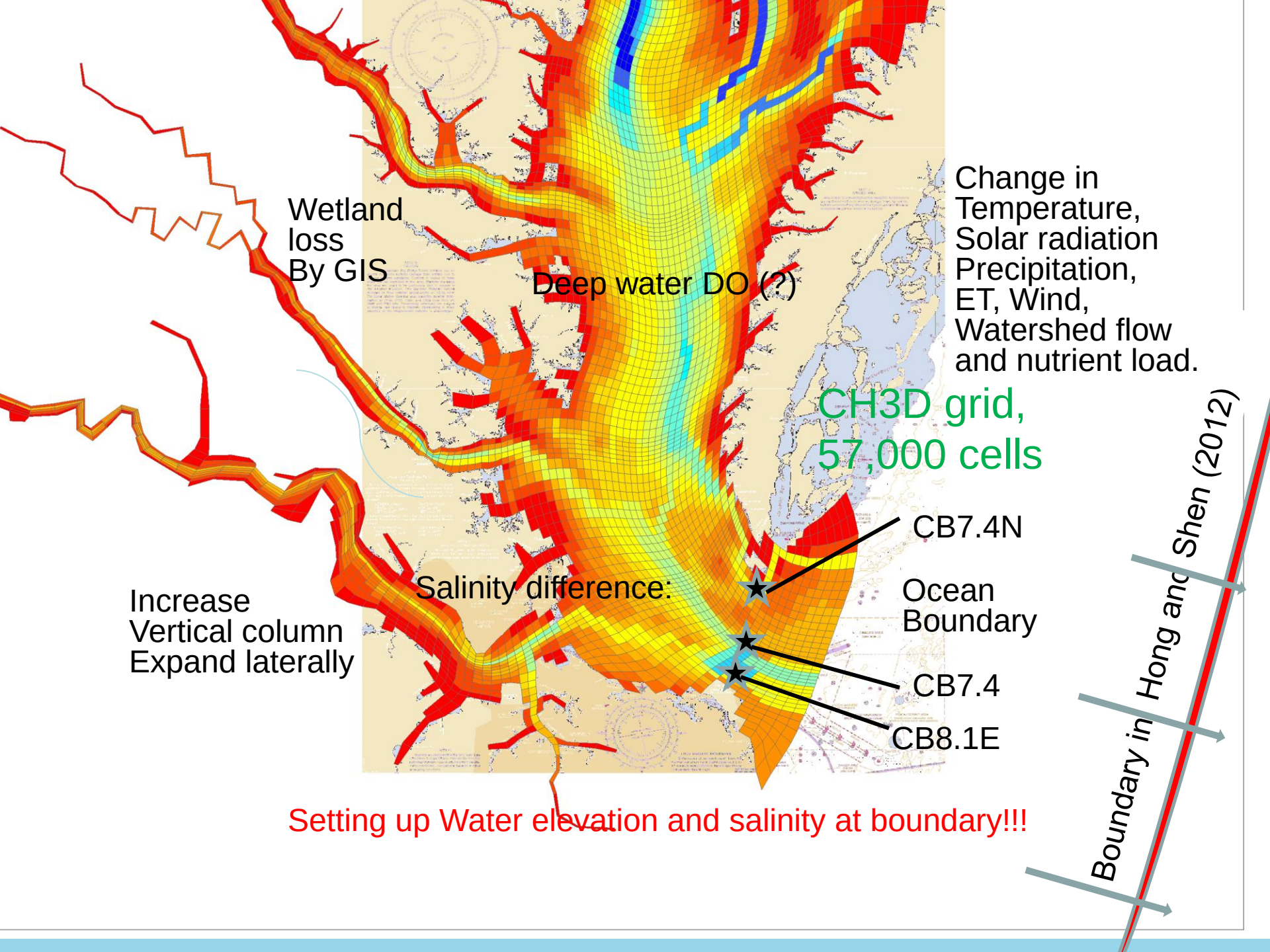
Bay mouth

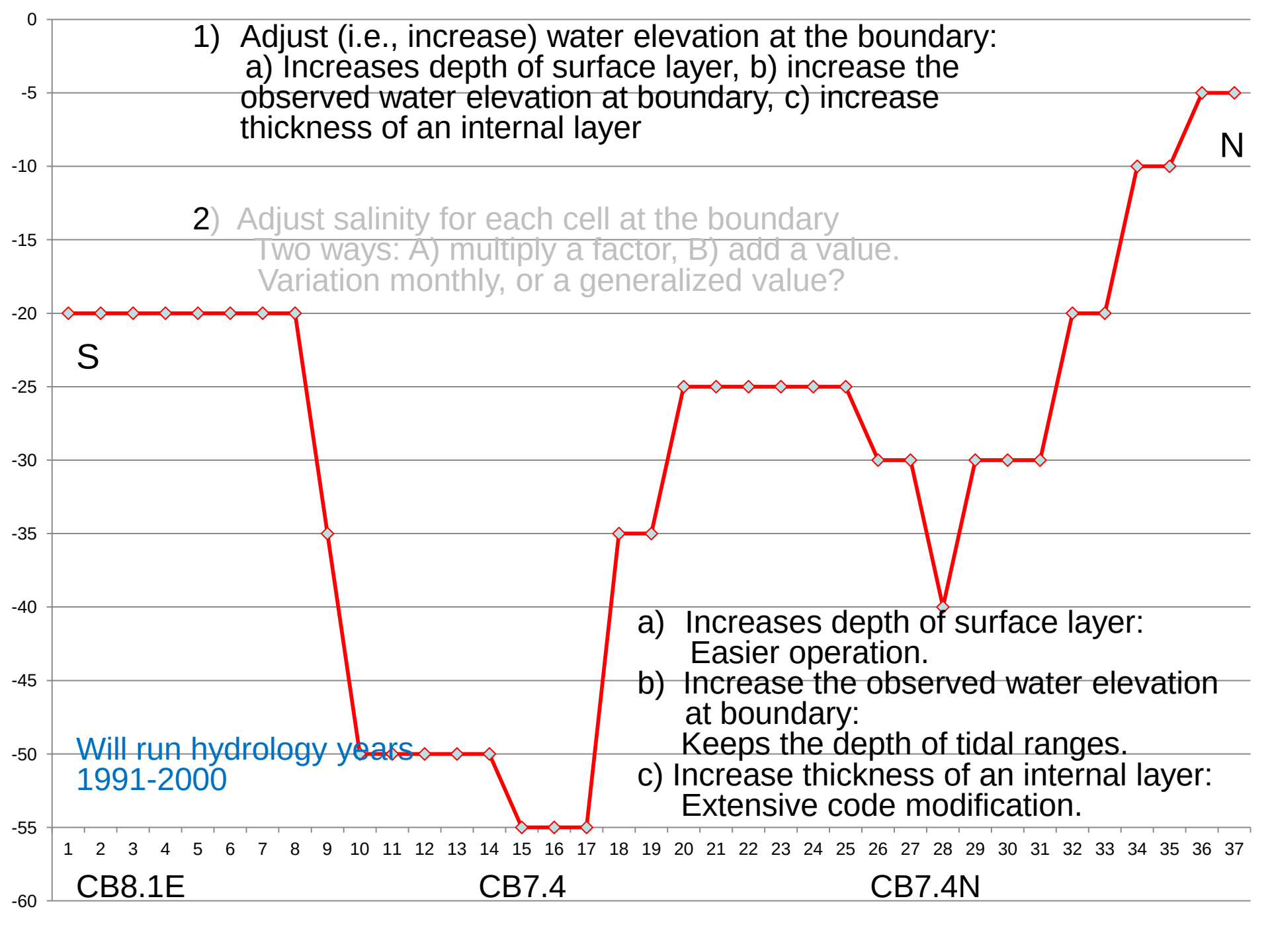
Latitude

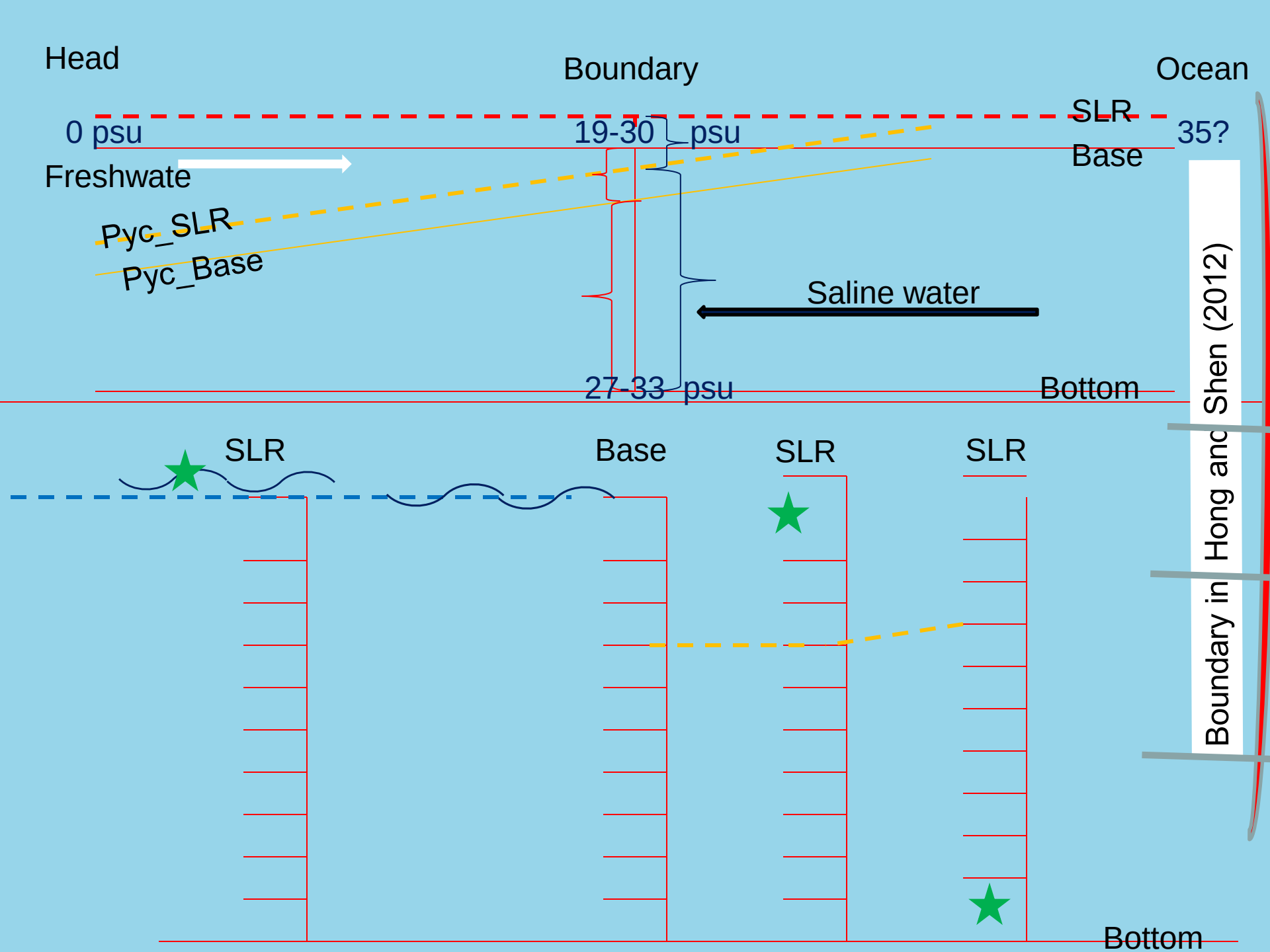
Bay head

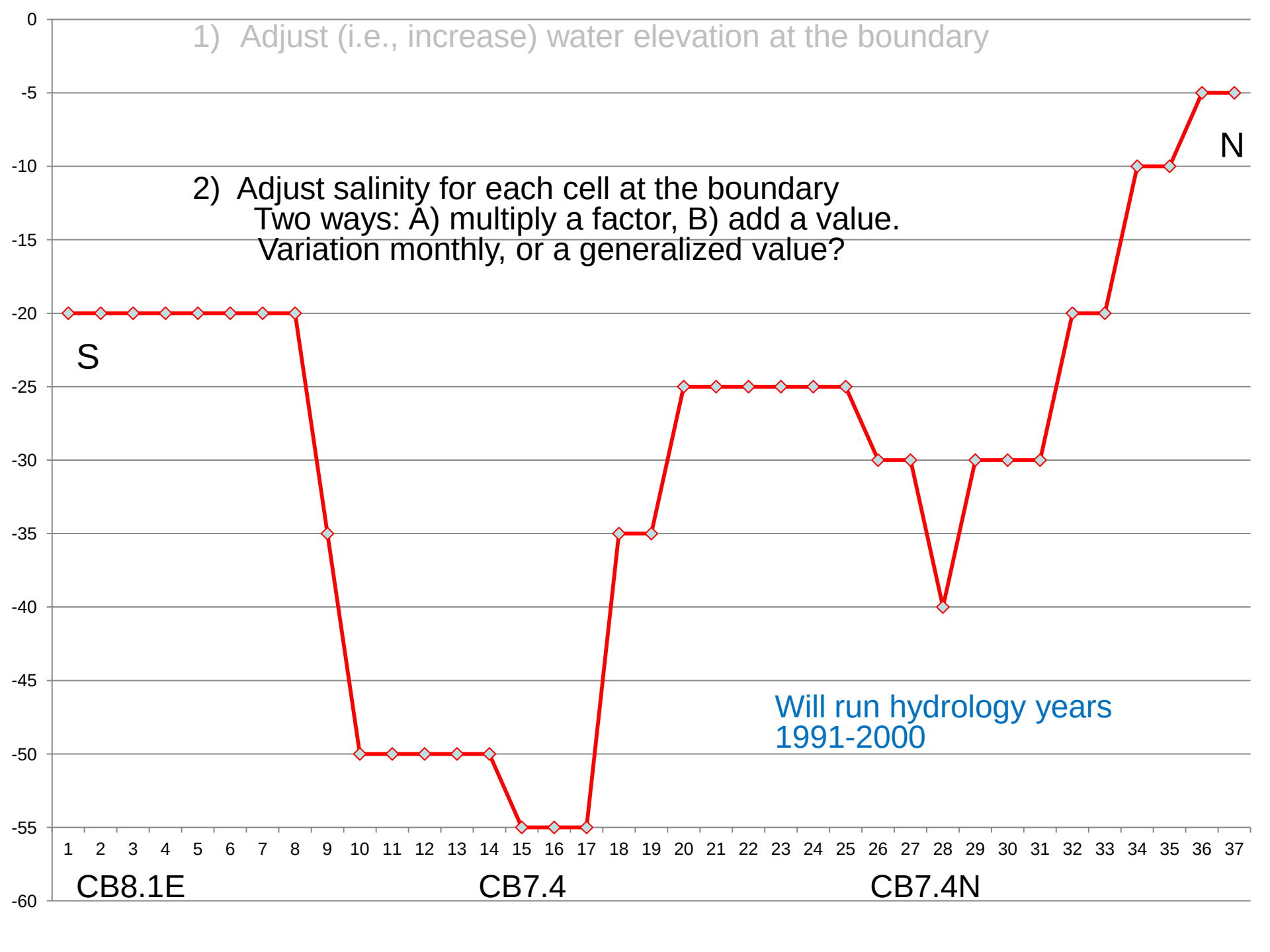
P50: 50 cm Sea Level Rise

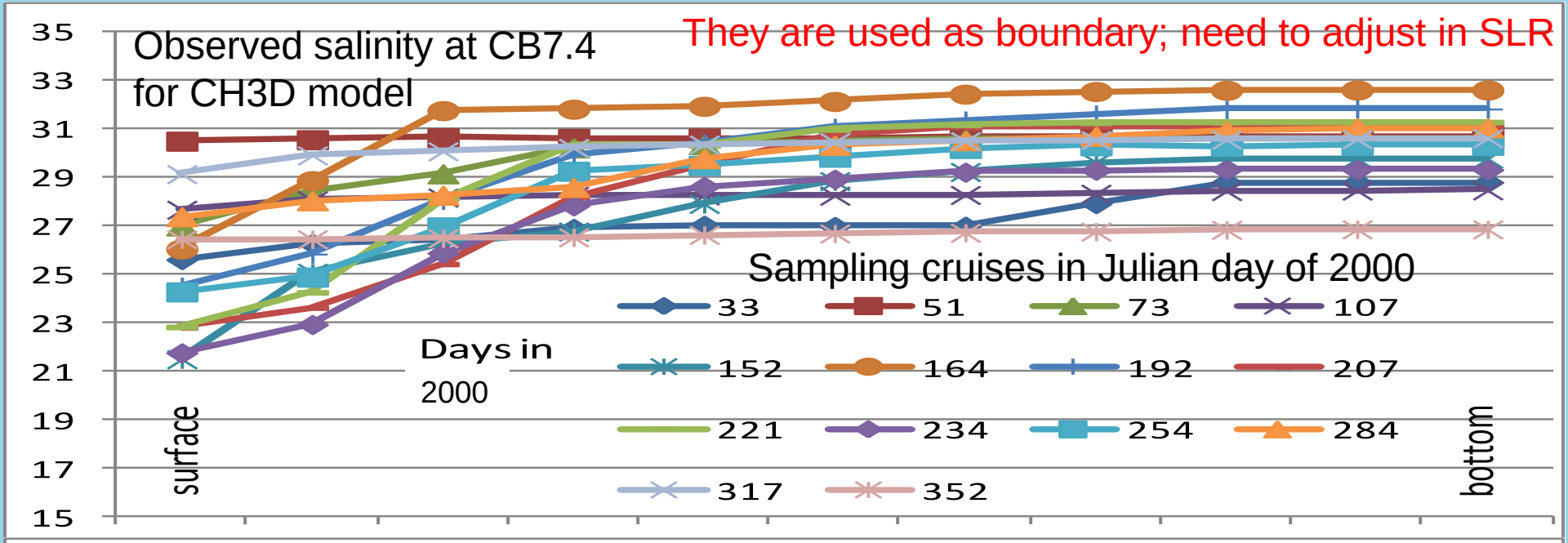
From Hong and Shen (2012)

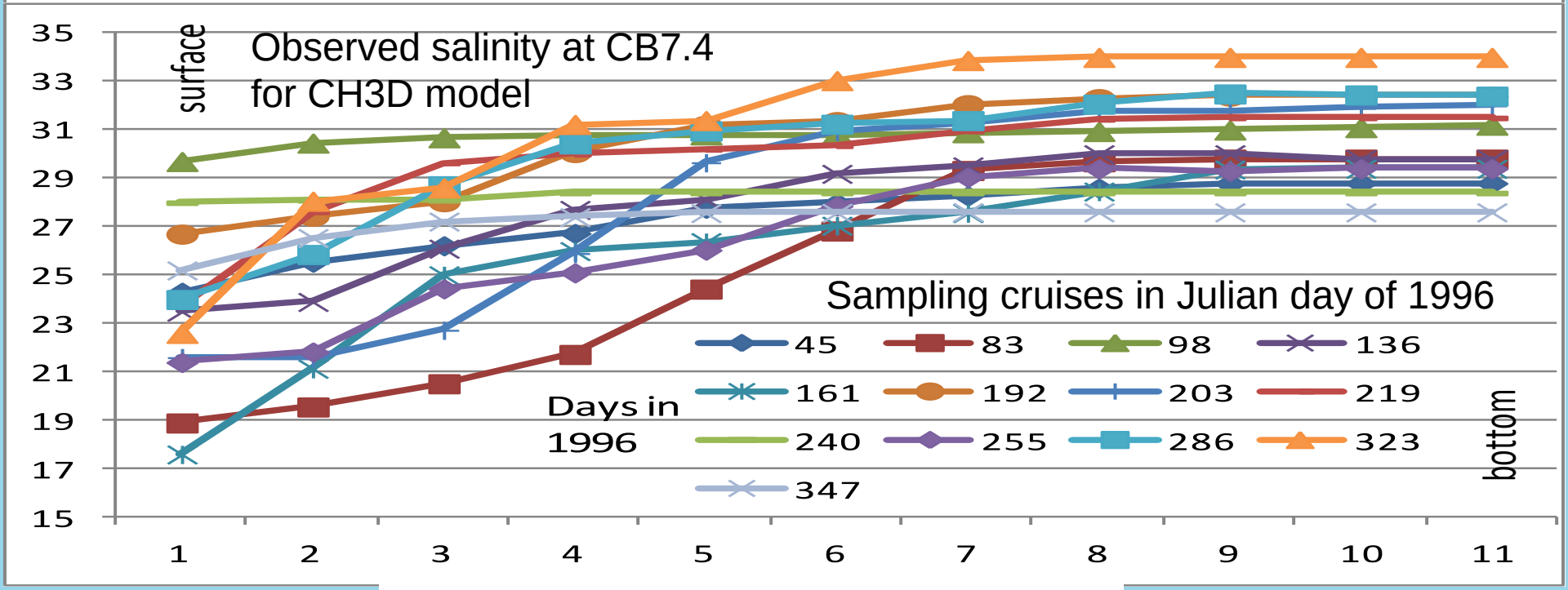

Wetland
loss
By GIS
Deep water DO (?)
Change in
Temperature,
Solar radiation
Precipitation,
ET, Wind,
Watershed flow
and nutrient load.
CH3D grid,
57,000 cells
CB7.4N
Salinity difference:
Ocean
Boundary
CB7.4
CB8.1E
Increase
Vertical column
Expand laterally
Boundary in Hong and Shen (2012)
Setting up Water elevation and salinity at boundary!!!


1) Adjust (i.e., increase) water elevation at the boundary:
a) Increases depth of surface layer, b) increase the observed water elevation at boundary, c) increase thickness of an internal layer
2) Adjust salinity for each cell at the boundary
Two ways: A) multiply a factor, B) add a value.
Variation monthly, or a generalized value?
S
N
Will run hydrology years 1991-2000
a) Increases depth of surface layer: Easier operation.
b) Increase the observed water elevation at boundary: Keeps the depth of tidal ranges.
c) Increase thickness of an internal layer: Extensive code modification.
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
CB8.1E
CB7.4
CB7.4N

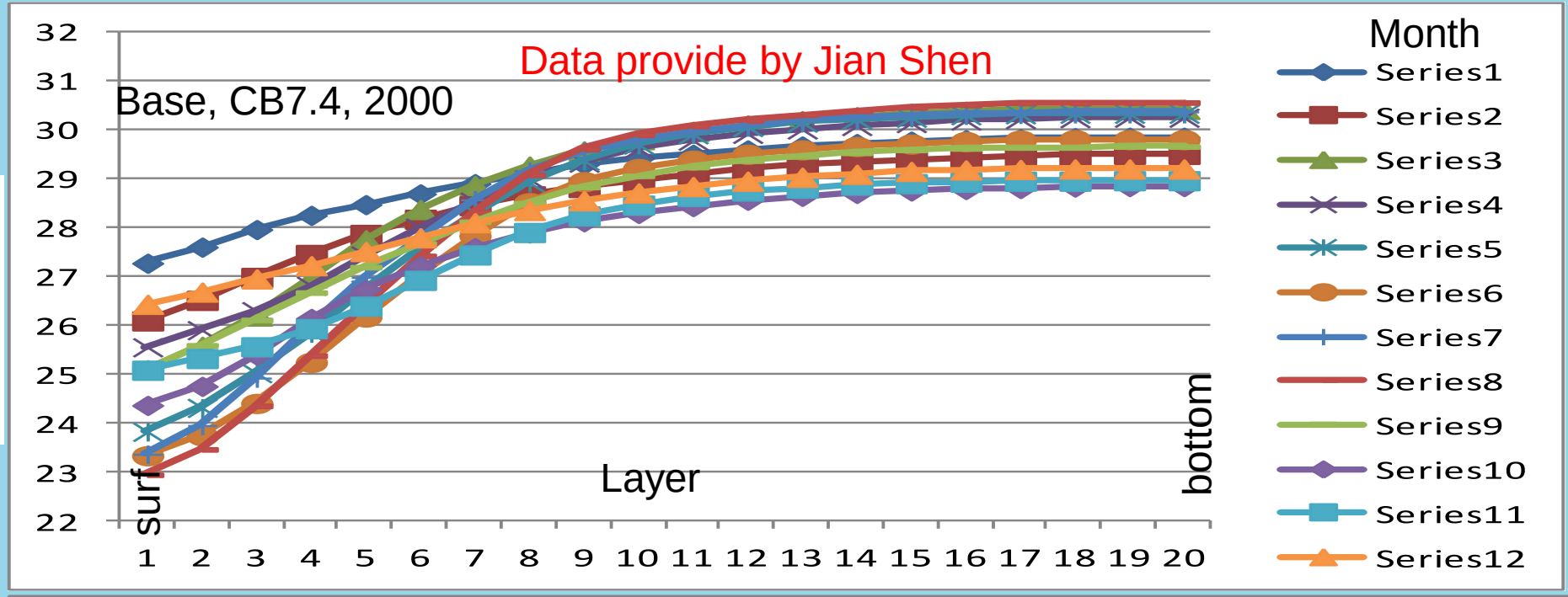

Head
Boundary
Ocean
SLR
0 psu
19-30 psu
35?
Base
Freshwate
Pyc_SLR
Pyc_Base
Saline water
27-33 psu
Bottom
SLR
Base
SLR
SLR
Boundary in Hong and Shen (2012)
Bottom

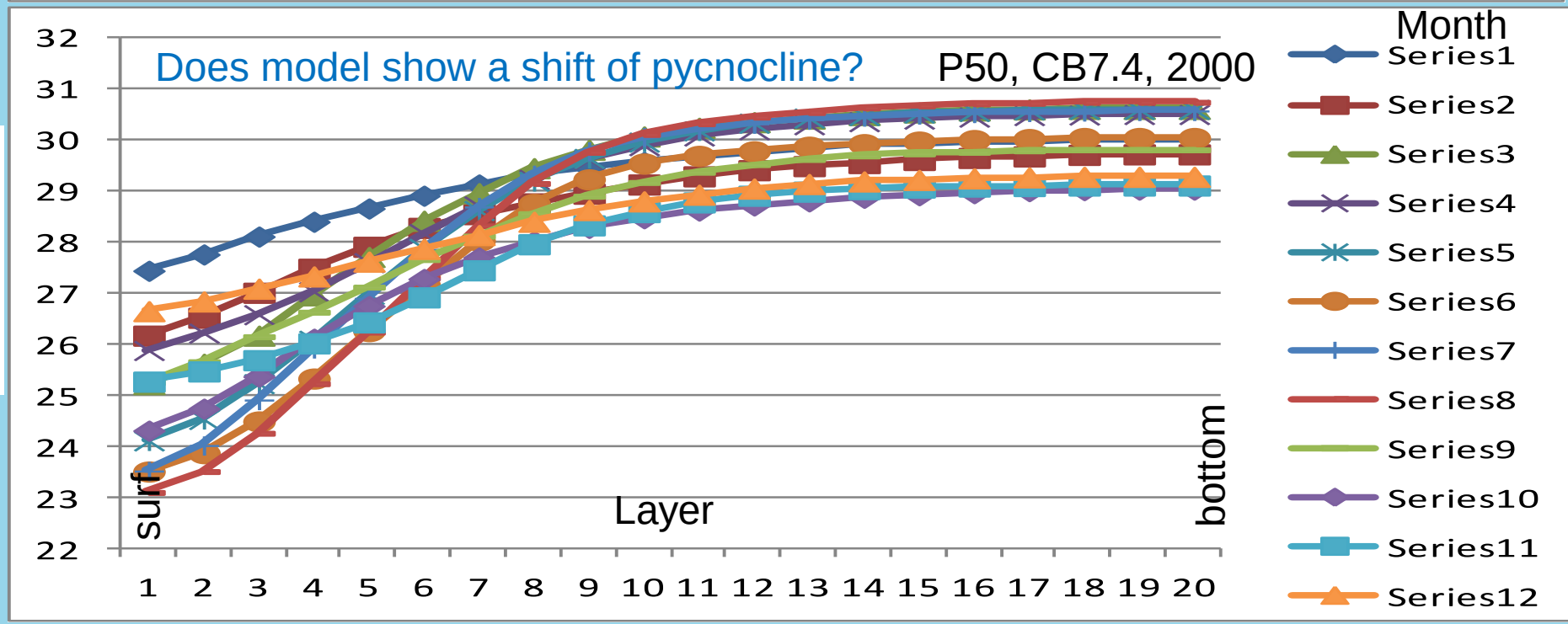

1) Adjust (i.e., increase) water elevation at the boundary
2) Adjust salinity for each cell at the boundary
Two ways: A) multiply a factor, B) add a value.
Variation monthly, or a generalized value?
S
N
Will run hydrology years
1991-2000
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
CB8.1E
CB7.4
CB7.4N



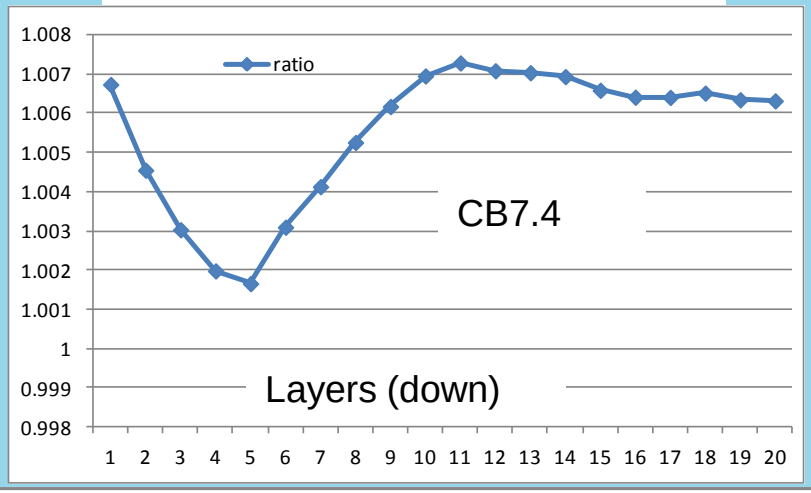


Layers down, each layer depth = 5 feet

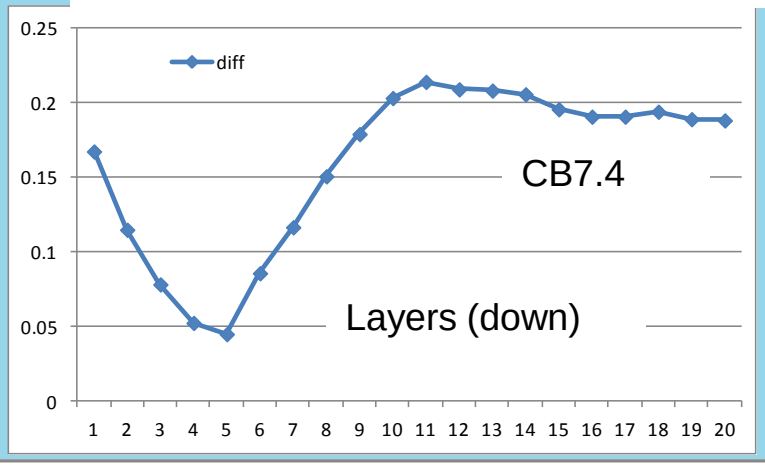

Data provide by Jian Shen
Base, CB7.4, 2000
Salinity (psu)
32
31
30
29
28
27
26
25
24
23
22
surf
bottom
Layer
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Month
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Series11
Series12

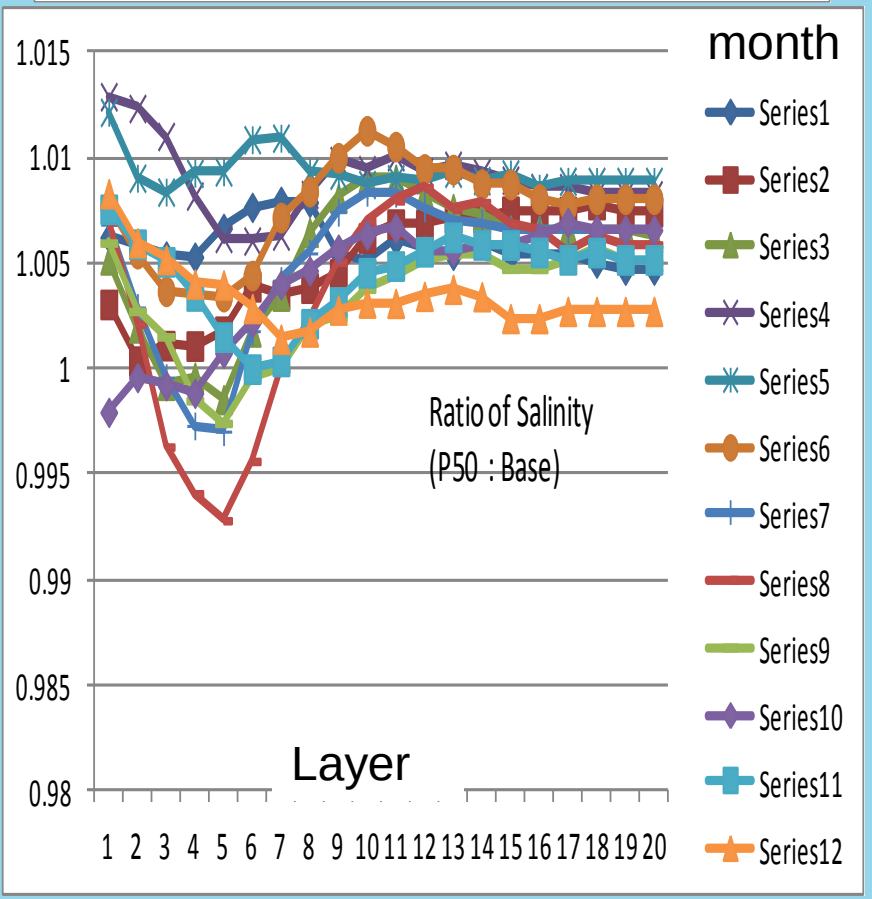

Does model show a shift of pycnocline?
P50, CB7.4, 2000
Salinity (psu)
32
31
30
29
28
27
26
25
24
23
22
surf
bottom
Layer
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Month
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Series11
Series12

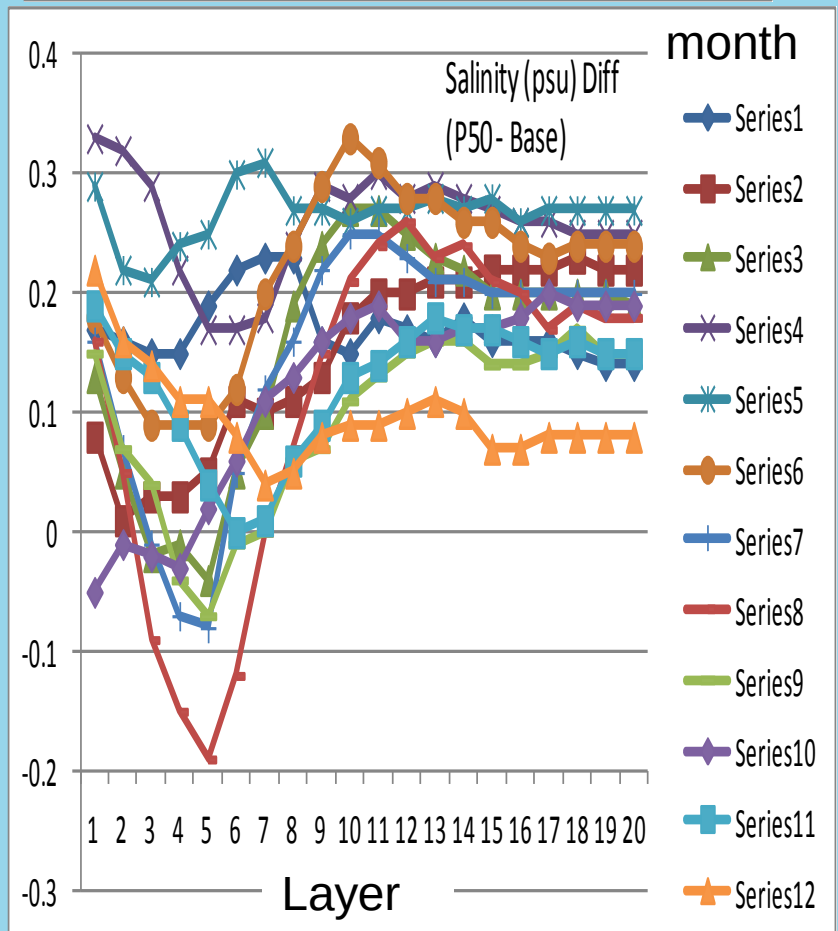
Ratio of Salinity : P50 : Base



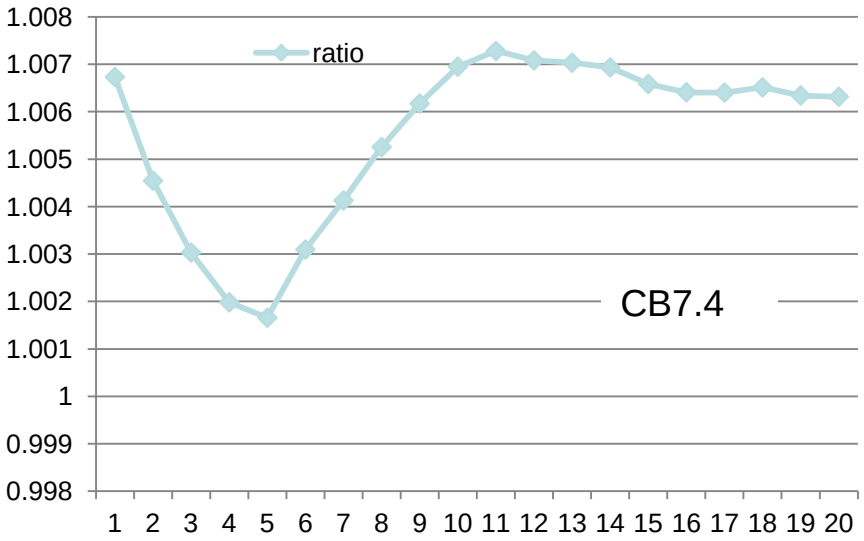
Salinity (psu) Diff (P50 - Base), Shen







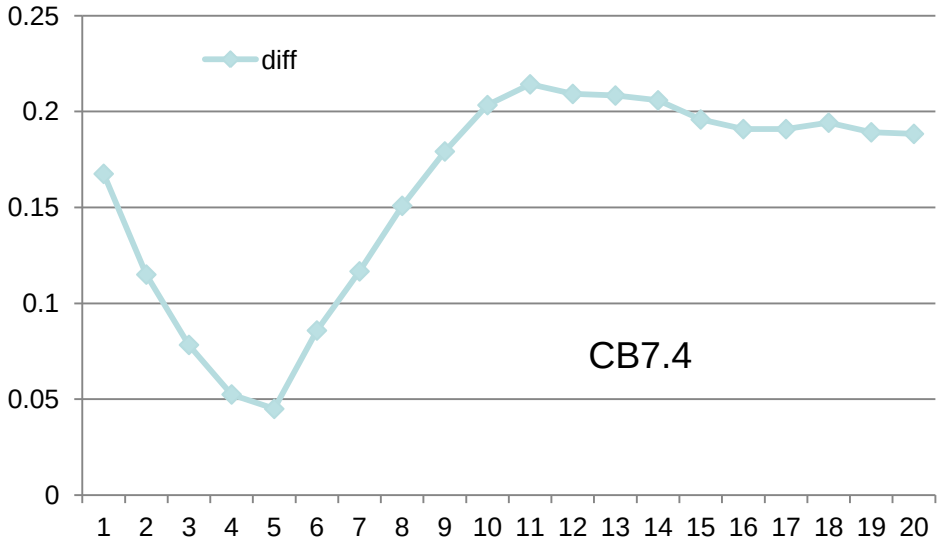
Ratio of salinity (P50 : Base)



Layers (down)

Factor : 1.00 to 1.011
Factor: 1.01 to 1.021

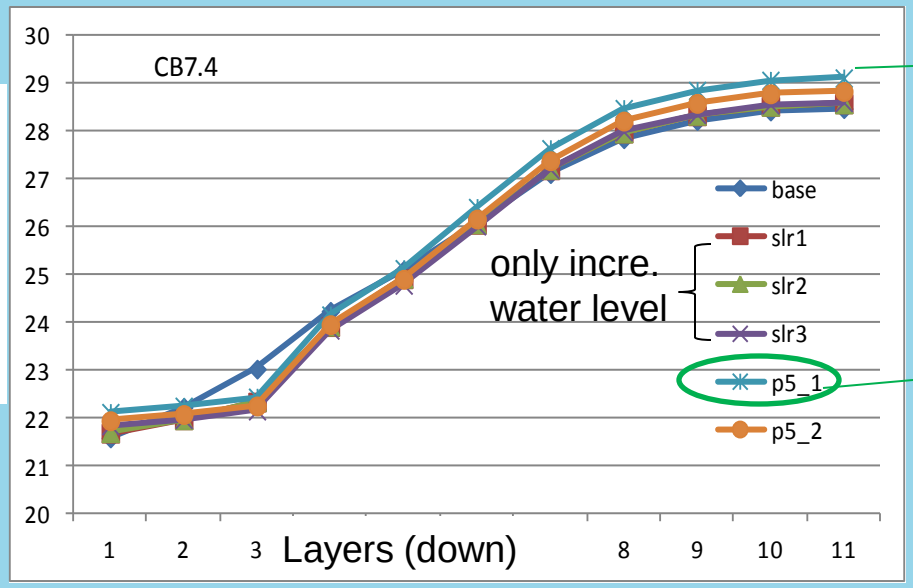
Salinity (psu) difference (P50 - Base)

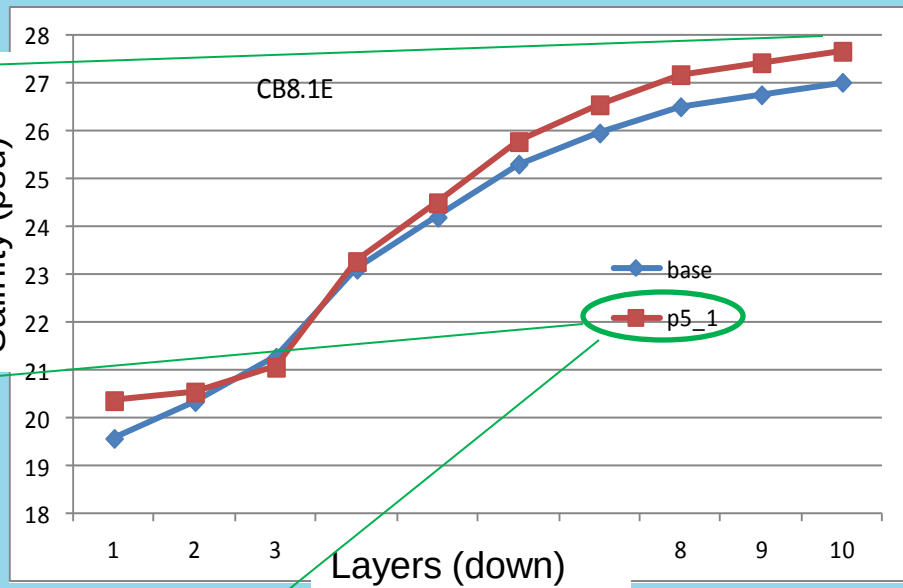


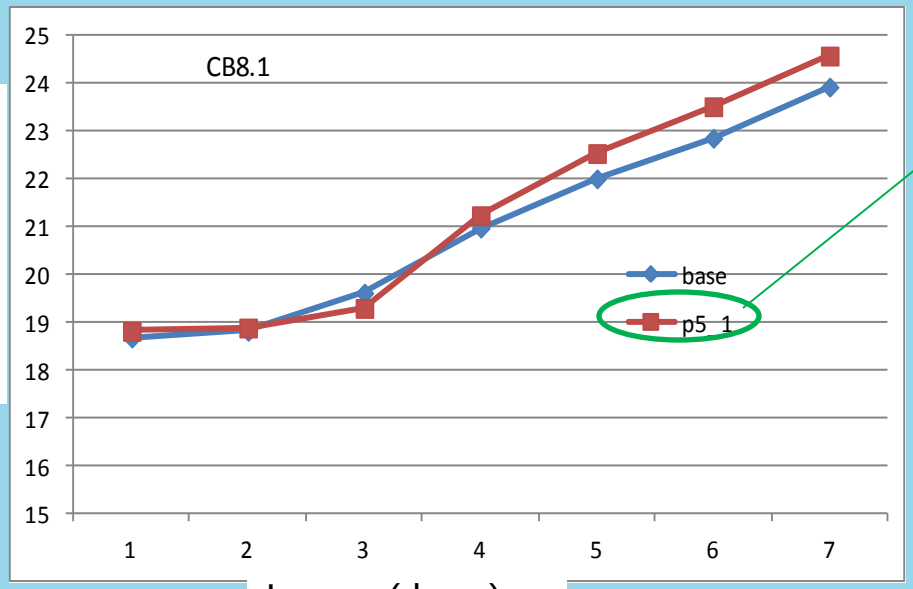
Layers (down)

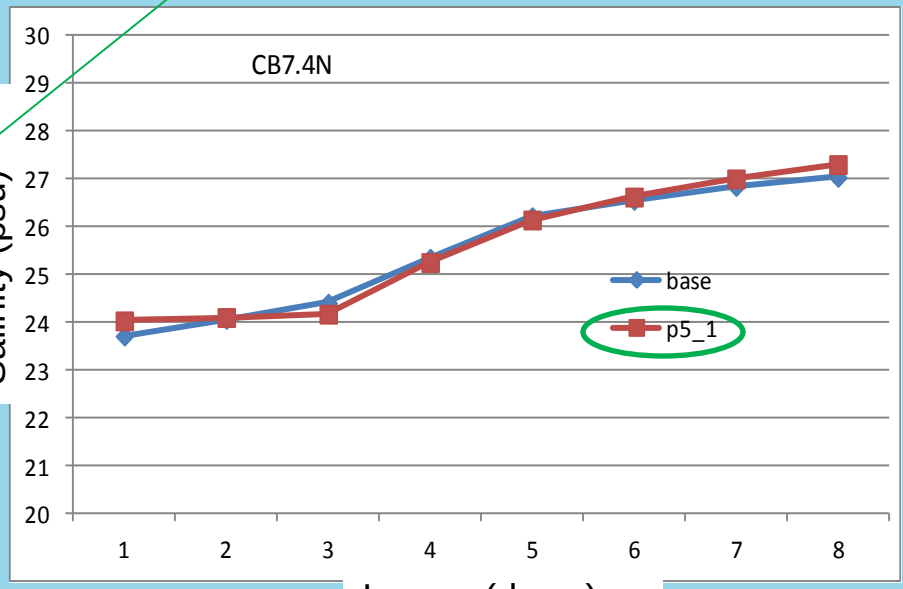
Add: 0.1.00 to 1.011
Factor: 1.01 to 1.021
nlaye
+ 0.001x nlayer

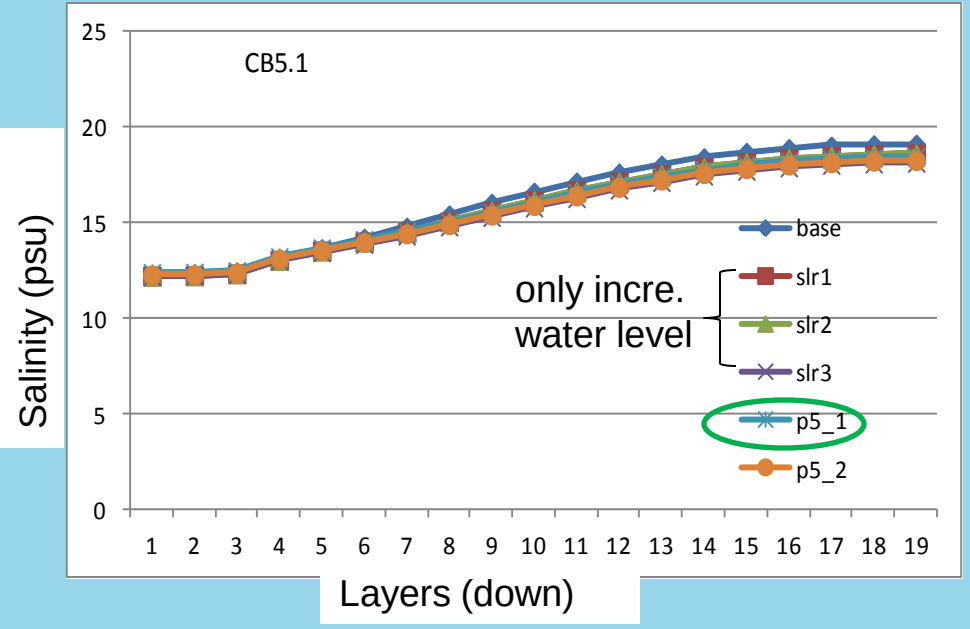
Data provide by Jian Shen

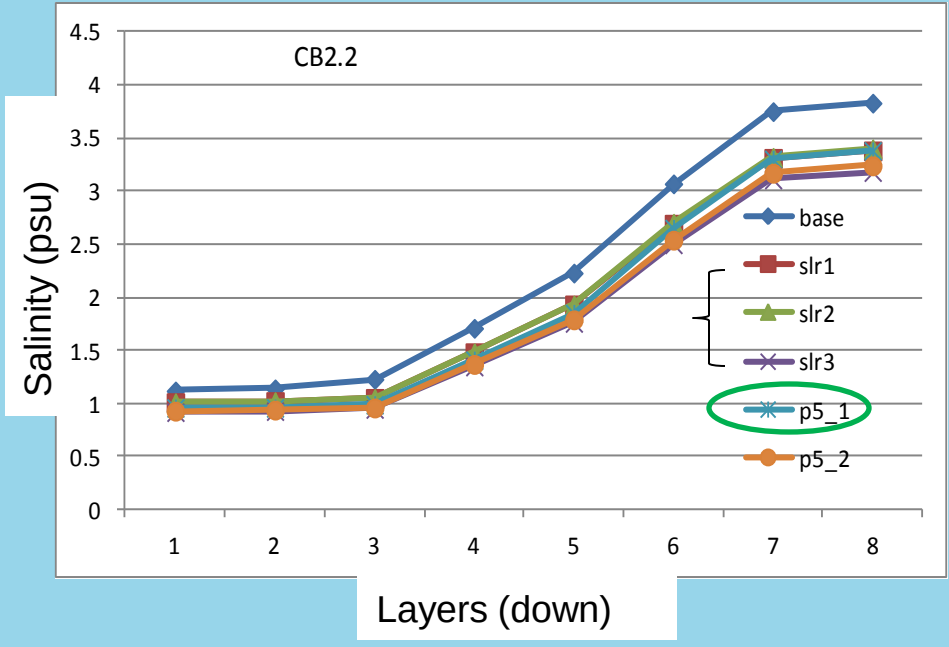

CB7.4
Salinity (psu)
Layers (down)
base
slr1
slr2
slr3
p5_1
p5_2
only incre.
water level

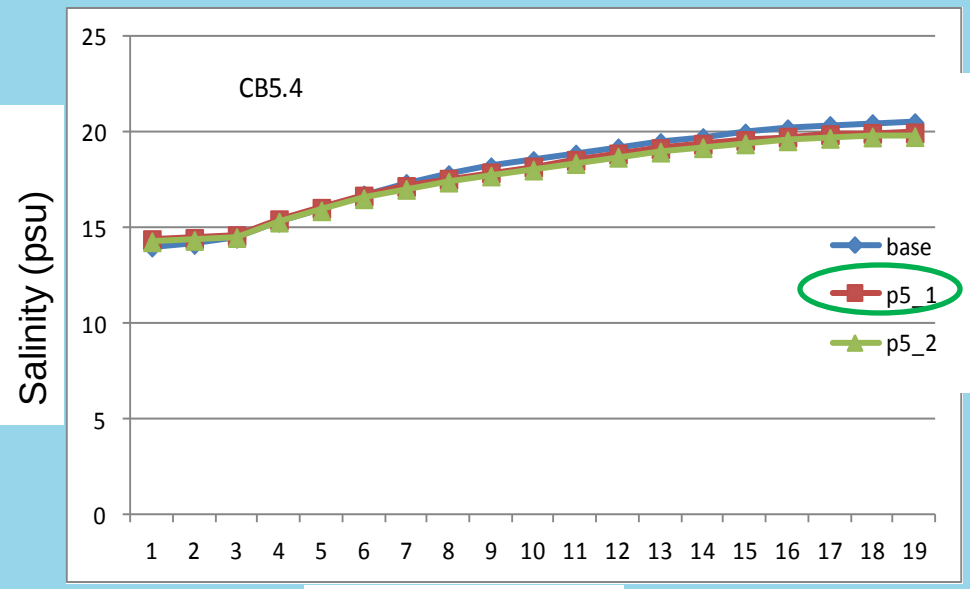

CB8.1E
Salinity (psu)
Layers (down)
base
p5_1

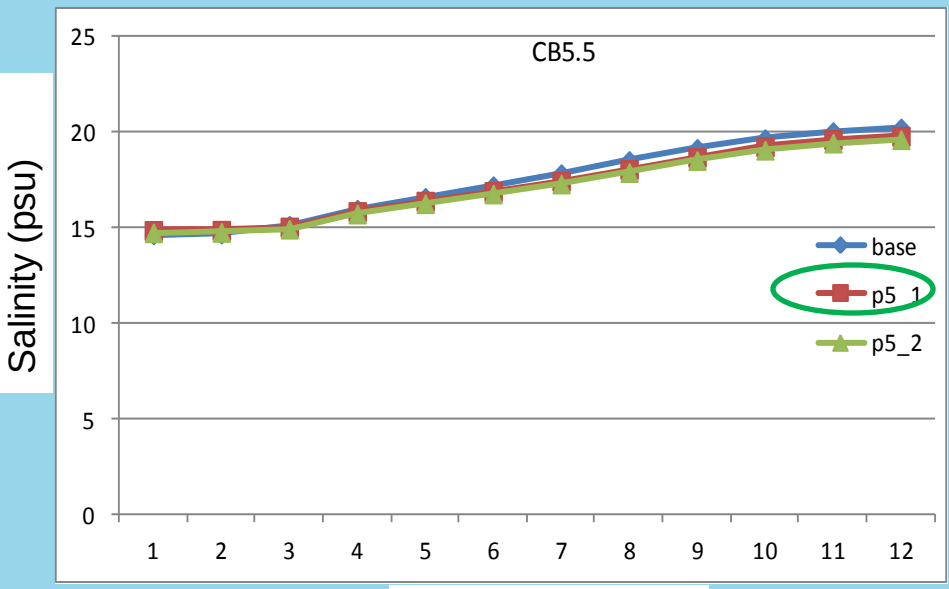

CB8.1
Salinity (psu)
Layers (down)
base
p5_1

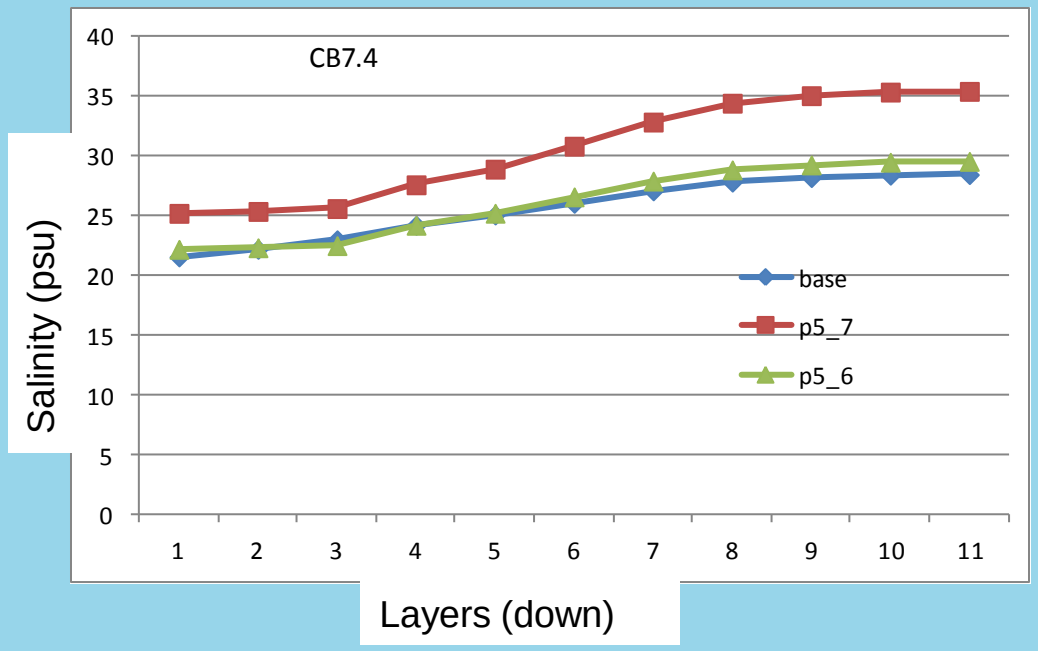

CB7.4N
Salinity (psu)
Layers (down)
base
p5_1

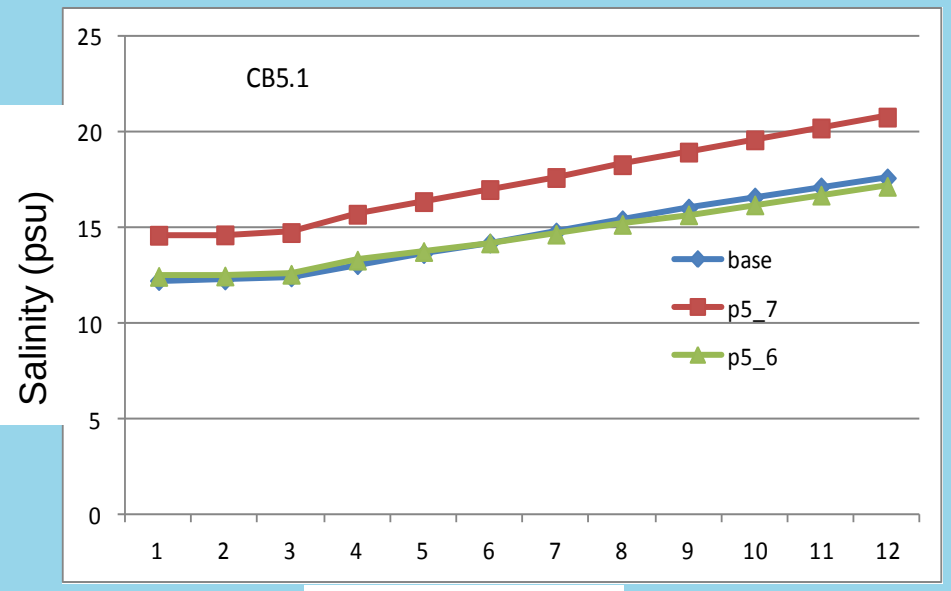

CB5.1
Salinity (psu)
Layers (down)
only incre.
water level
base
slr1
slr2
slr3
p5_1
p5_2

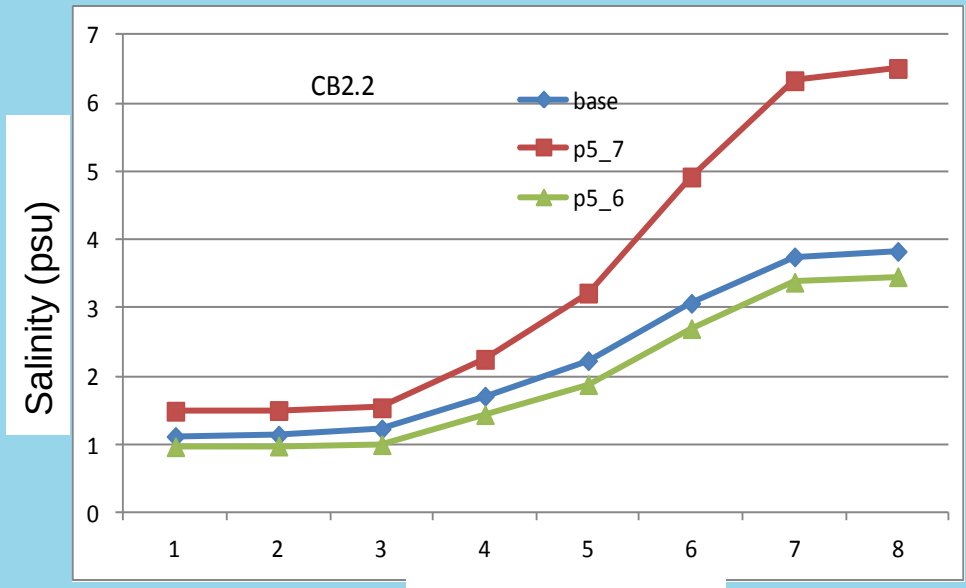

CB2.2
Salinity (psu)
Layers (down)
base
slr1
slr2
slr3
p5_1
p5_2


CB5.4
Salinity (psu)
Layers (down)
base
p5_1
p5_2

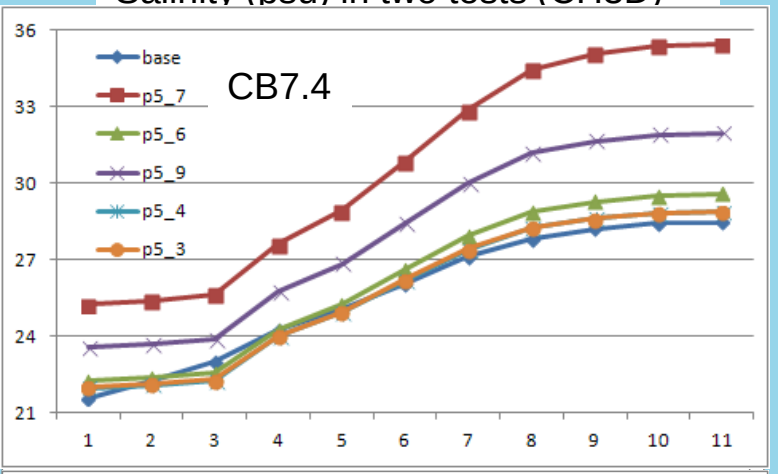

CB5.5
Salinity (psu)
Layers (down)
base
p5_1
p5_2

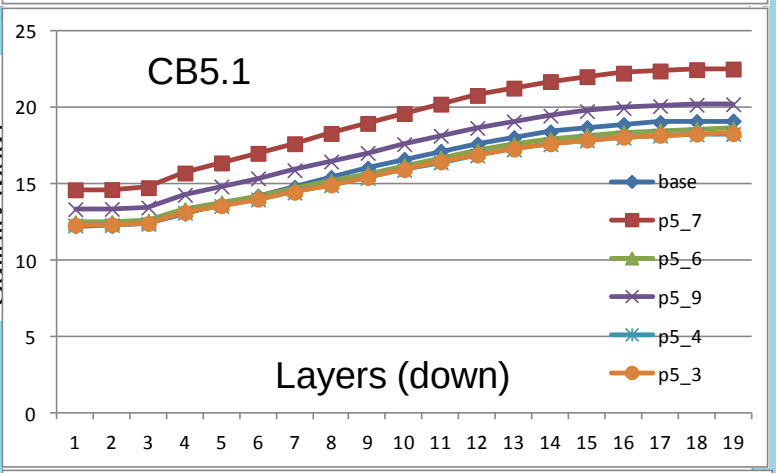

CB7.4
Salinity (psu)
Layers (down)
base
p5_7
p5_6
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
7
8
9
10
11

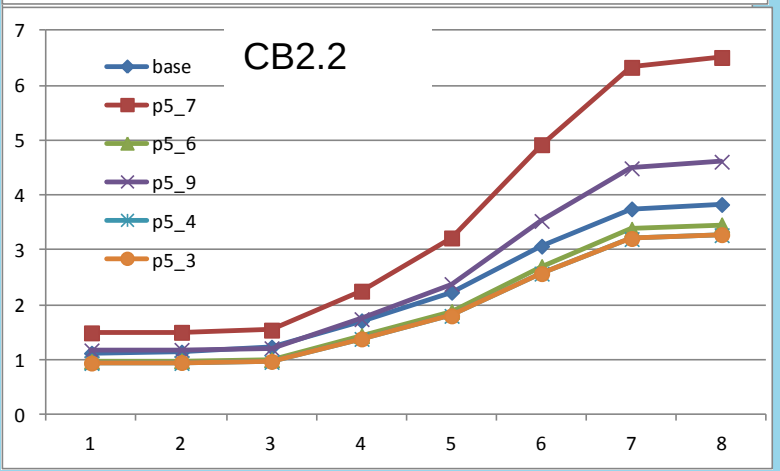

CB5.1
Salinity (psu)
Layers (down)
base
p5_7
p5_6
0
5
10
15
20
25
1
2
3
4
5
6
7
8
9
10
11
12


CB2.2
Salinity (psu)
Layers (down)
base
p5_7
p5_6
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8

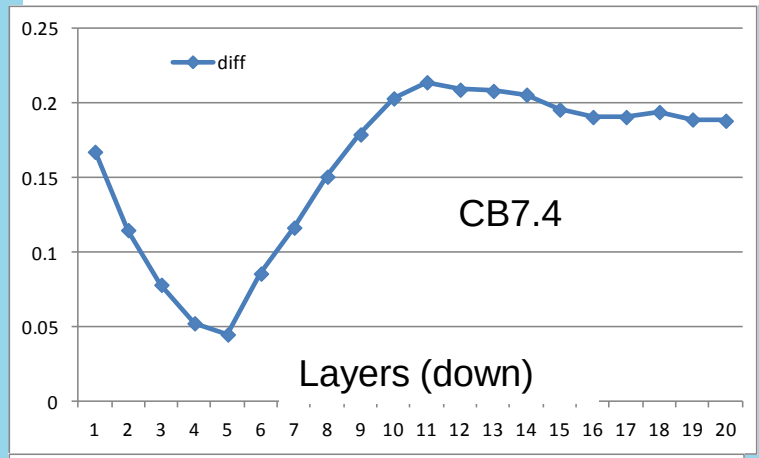
Salinity (psu) in two tests (CH3D)

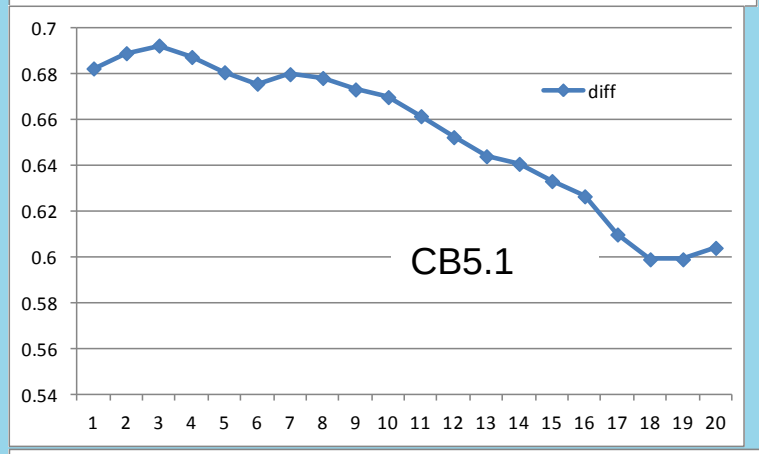


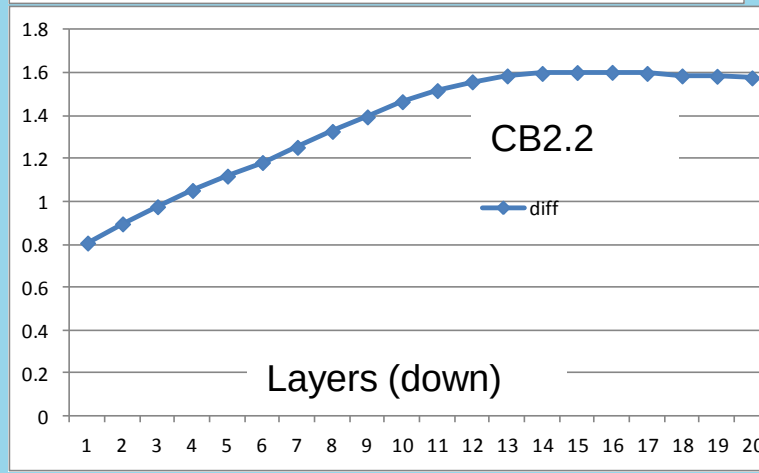




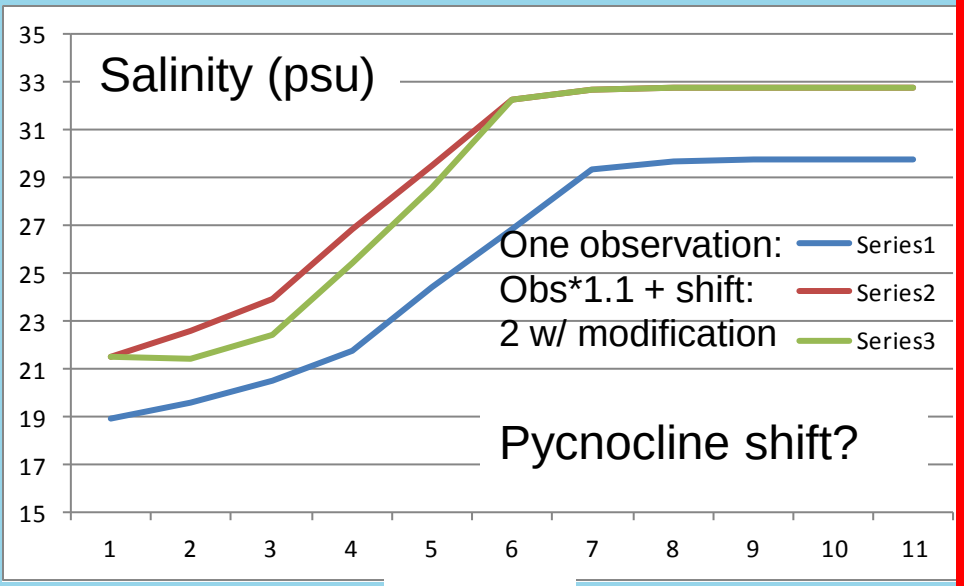
Salinity (psu) Diff (P50 - Base), Shen

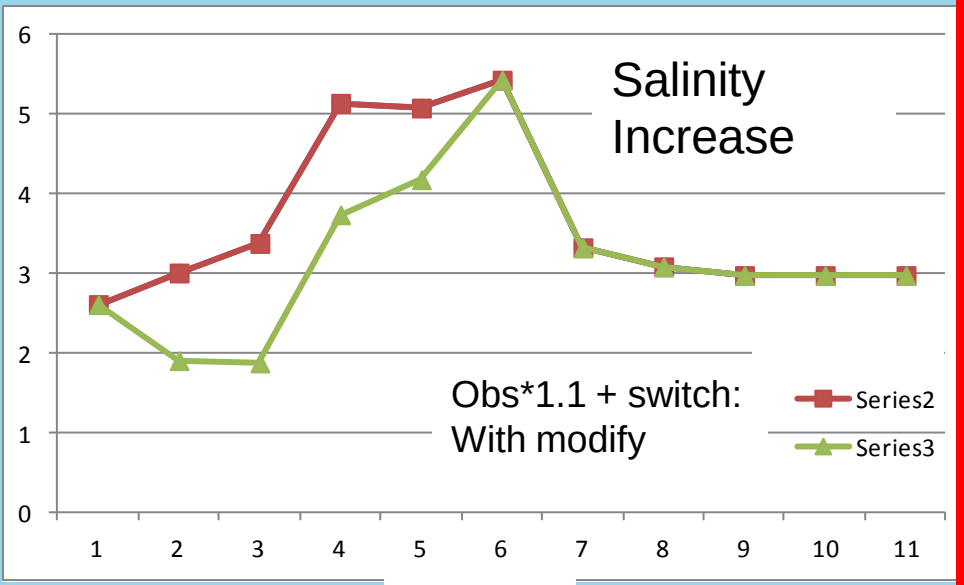




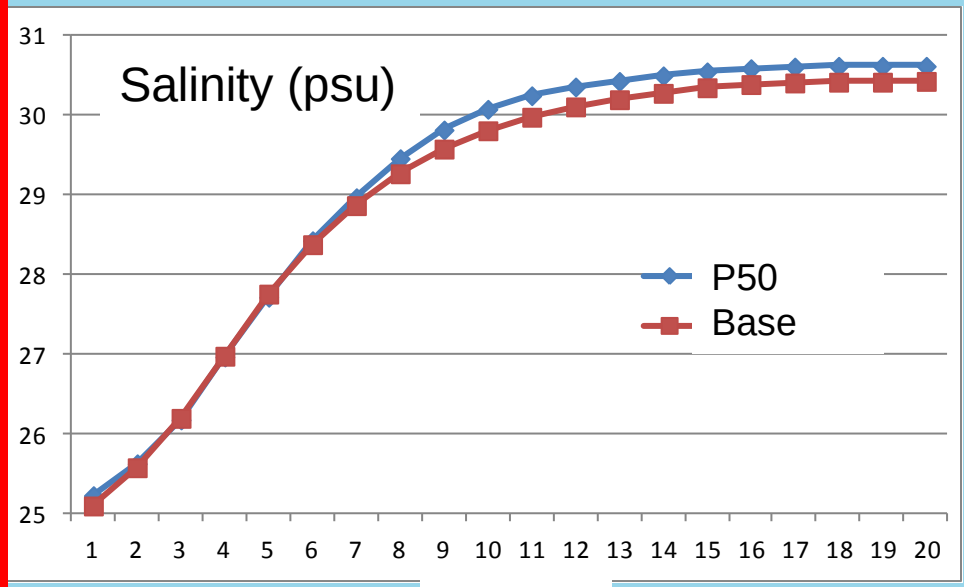


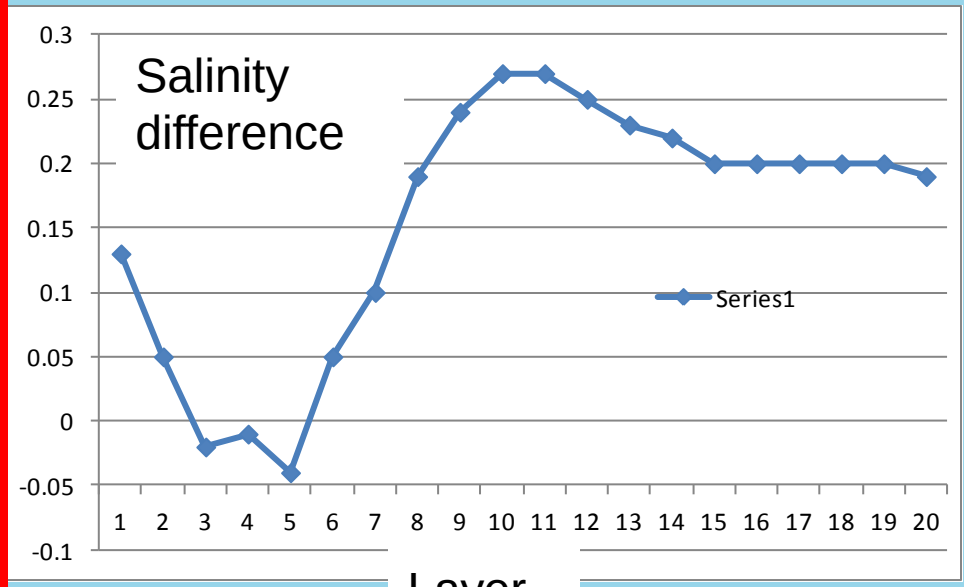
Imitated data for CB7.4 w.r.t. SLR

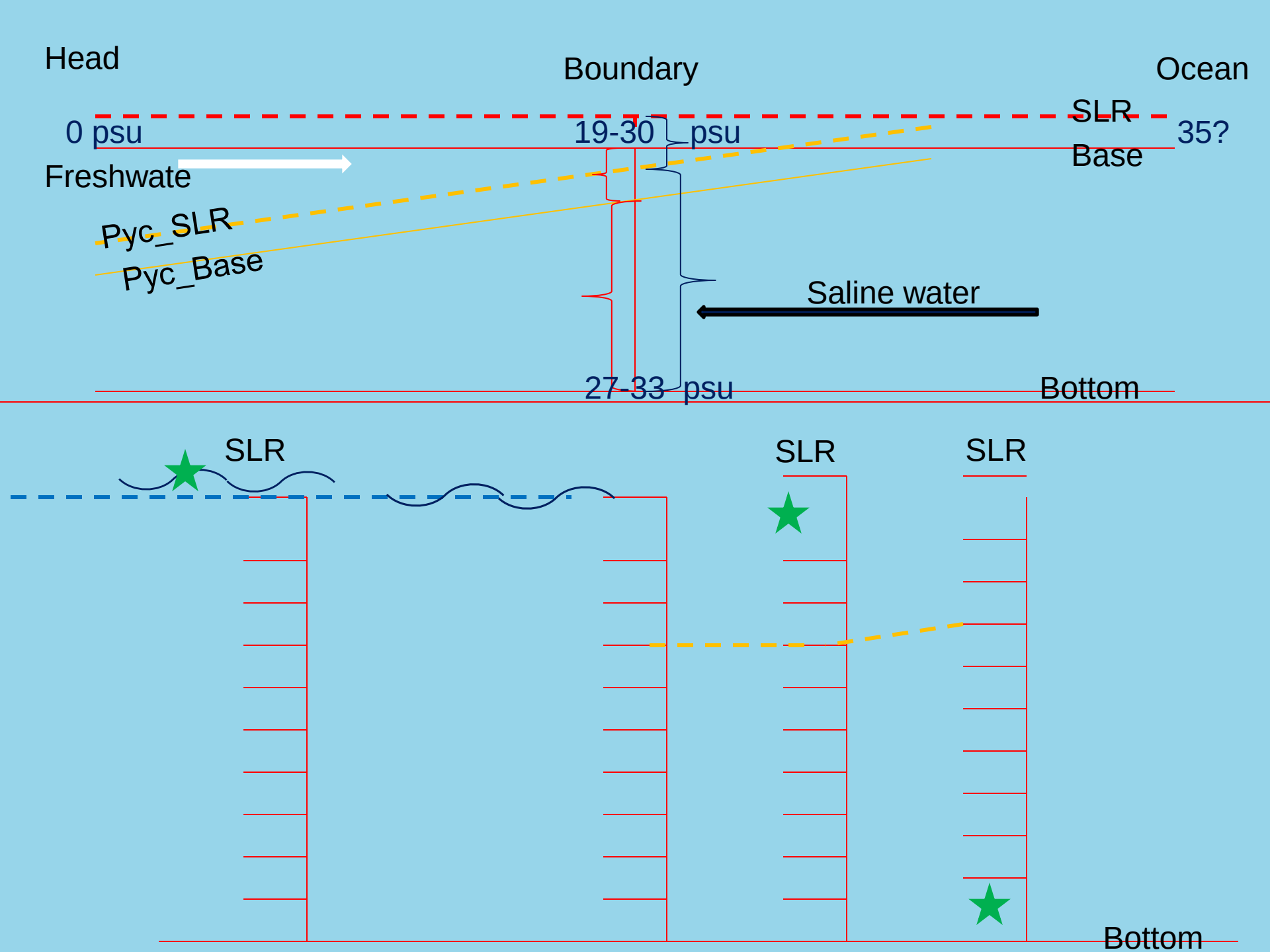




CB7.4 (From Shen's data)






Head
Boundary
Ocean
SLR
0 psu
19-30 psu
35?
Base
Freshwate
Pyc_SLR
Pyc_Base
Saline water
27-33 psu
Bottom
SLR
SLR
SLR
Bottom

Lesson learnt from trial tests on adjusting boundary salinity for SLR

Adjust salinity at boundary for 0.5 meter SLR

- The salinity changes are different among vertical cells.
- The changes vary daily and monthly.
- Pycnocline at CB7.4 gets higher at SLR, however, it is hard to be represented in the CH3D boundary due to its depth interval (~1.53 meter) and variation seasonally in the base case.
- Boundary conditions differ in different years, but here is only 2000 simulated SRL (by Shen).
- Suggests: use factors to adjust salinity which vary in depths. So far the factors can only allow for monthly variation if we only simulate 2000 hydrology, but cannot use such monthly variation to other years. Thus, using a single factor for all years.
- These is no data on changes along the horizontal boundary, therefore, no horizontal variation of the factors.
- While the variations are reflected from the variations of Obs.

- So far we haven’t obtain satisfactory factors to adjust the vertical boundary, however, approximate values may be achieved through more trial tests.
- The information used for the adjustment is limited. It is impossible to obtain real values for the adjustment.
- The salinity responses in the inner Bay should also be examined to confirm the boundary adjustment. However, the info used are from other models which may not yield similar responses in the inner Bay even the boundary are set the same.
- There is no enough information on the adjustments, therefore, our CH3D modeled sea level rise may not truly reflect the real cases.
- We recognize the limitations in the boundary setting and CH3D simulation of hydrology in SLR. Such reality should be noted in the afterwards studies that utilizes the CH3D SLR simulations.
- SLR may be better simulated if depth increase is on an interior layer, but it requires extensive code modification on CH3D, as well as ICM when simulating water quality.
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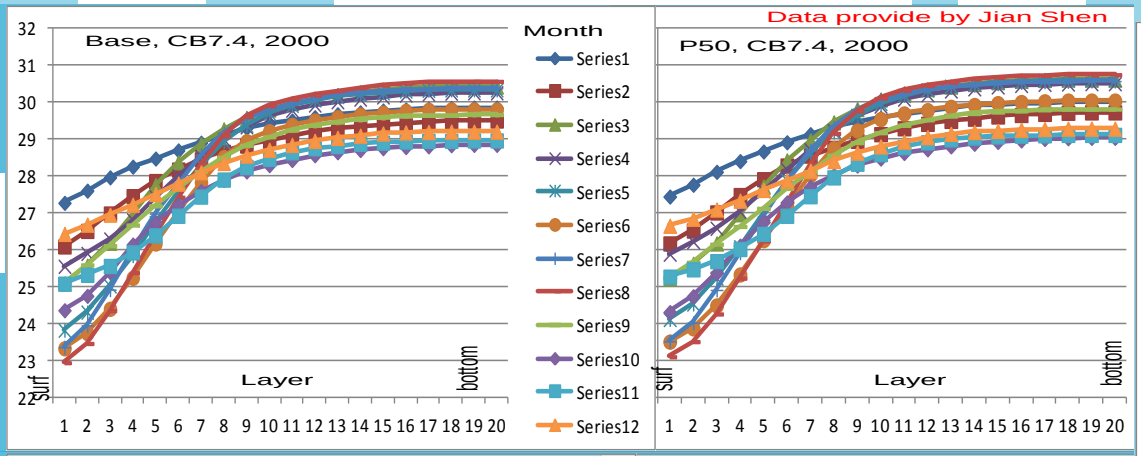
Thank you.

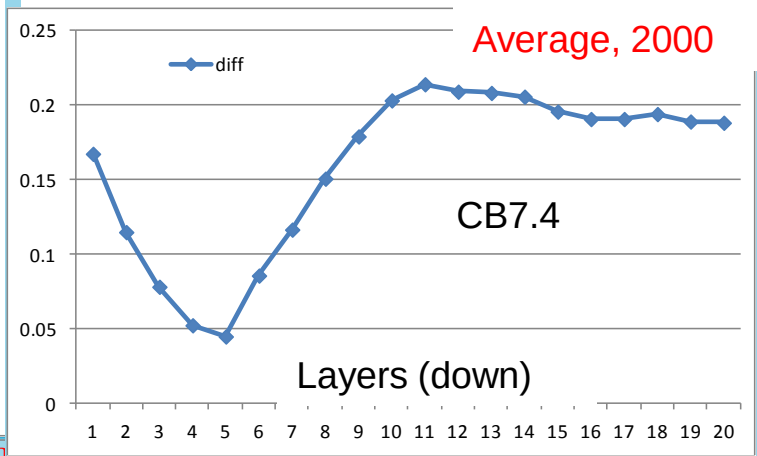
Base

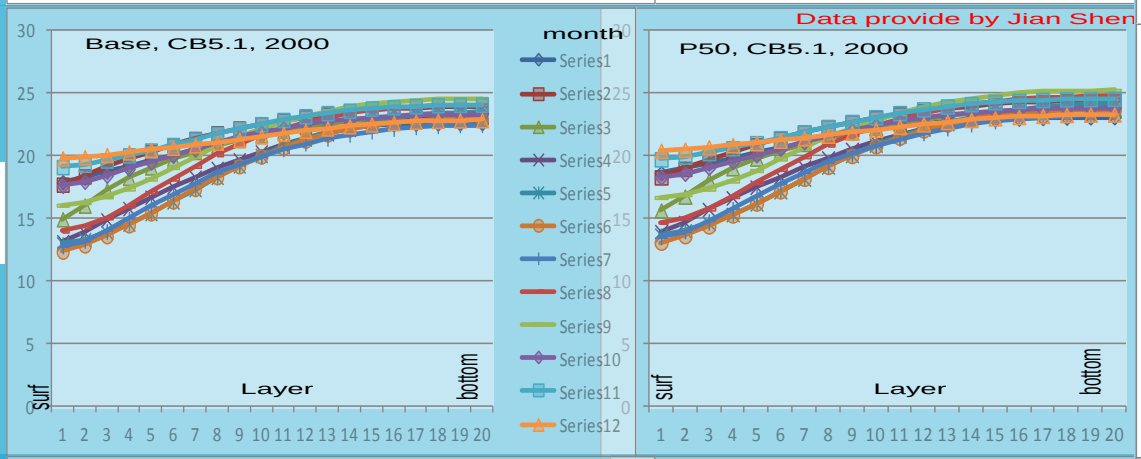
Salinity (monthly average, 2000)

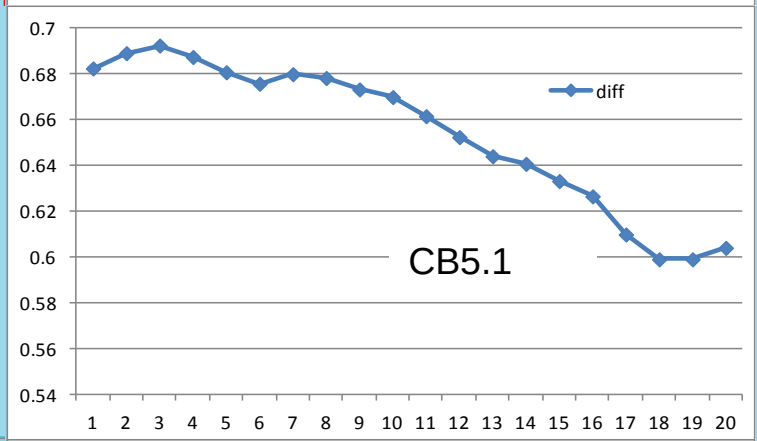
P50

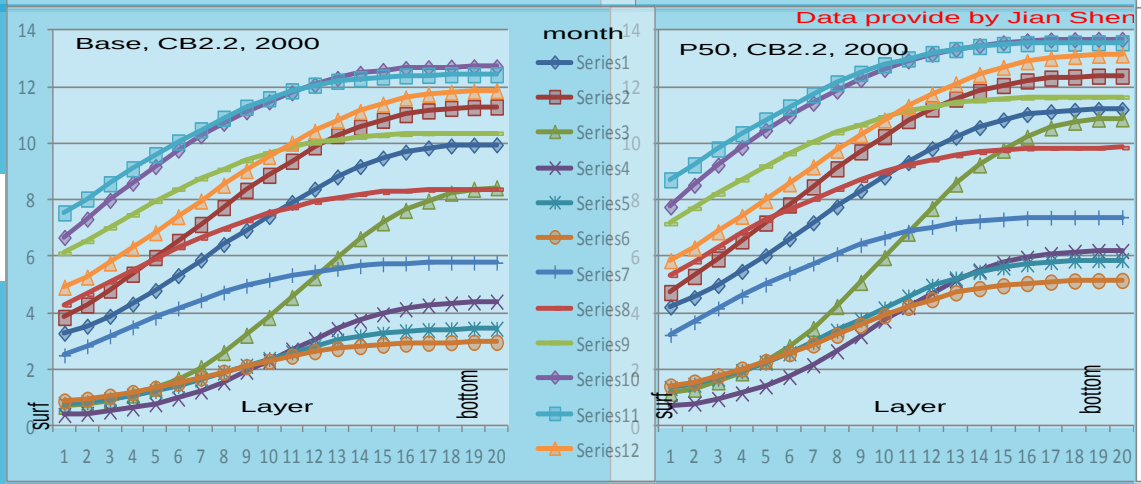
Salinity (psu) Diff (P50 - Base), Shen Average, 2000

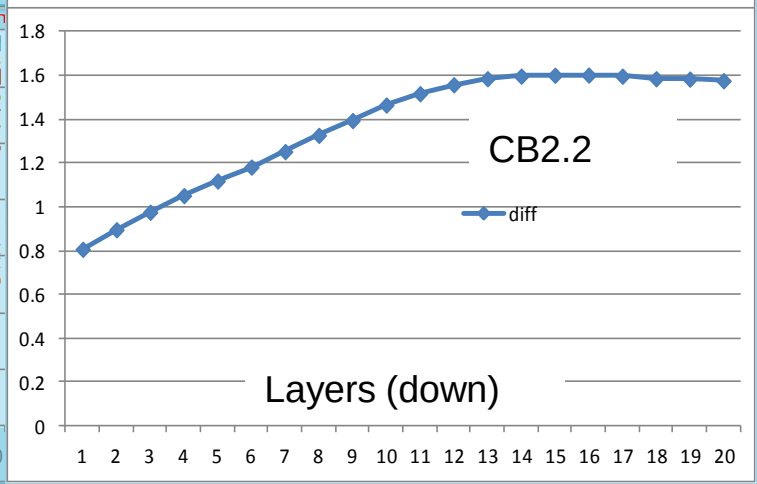




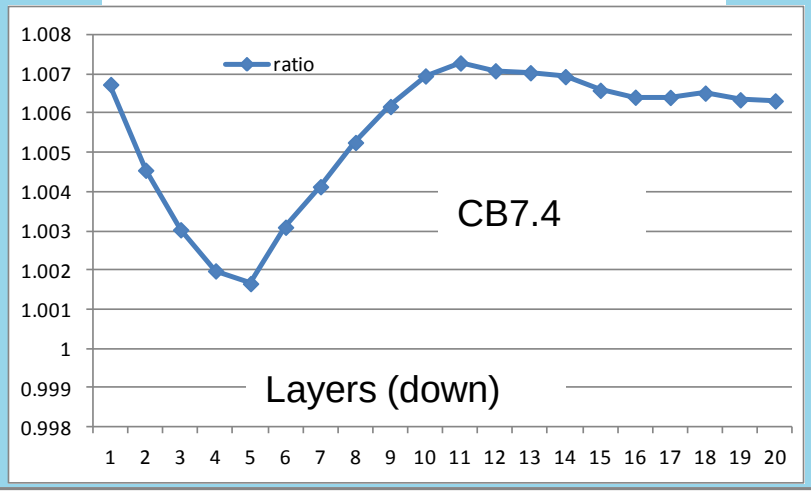




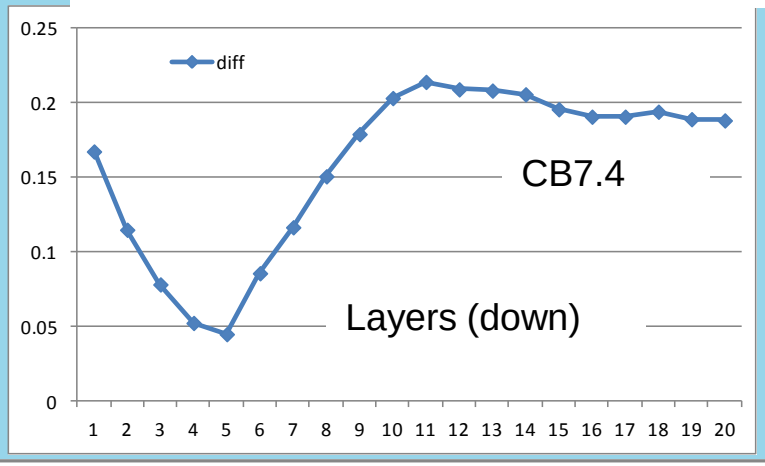


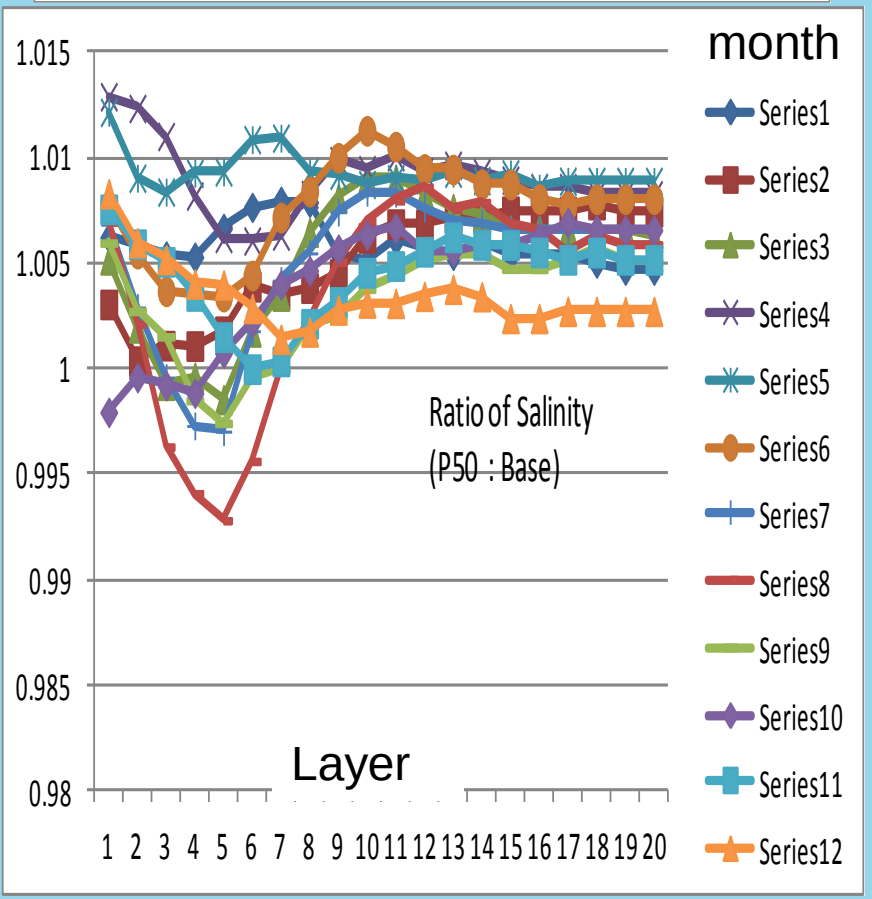


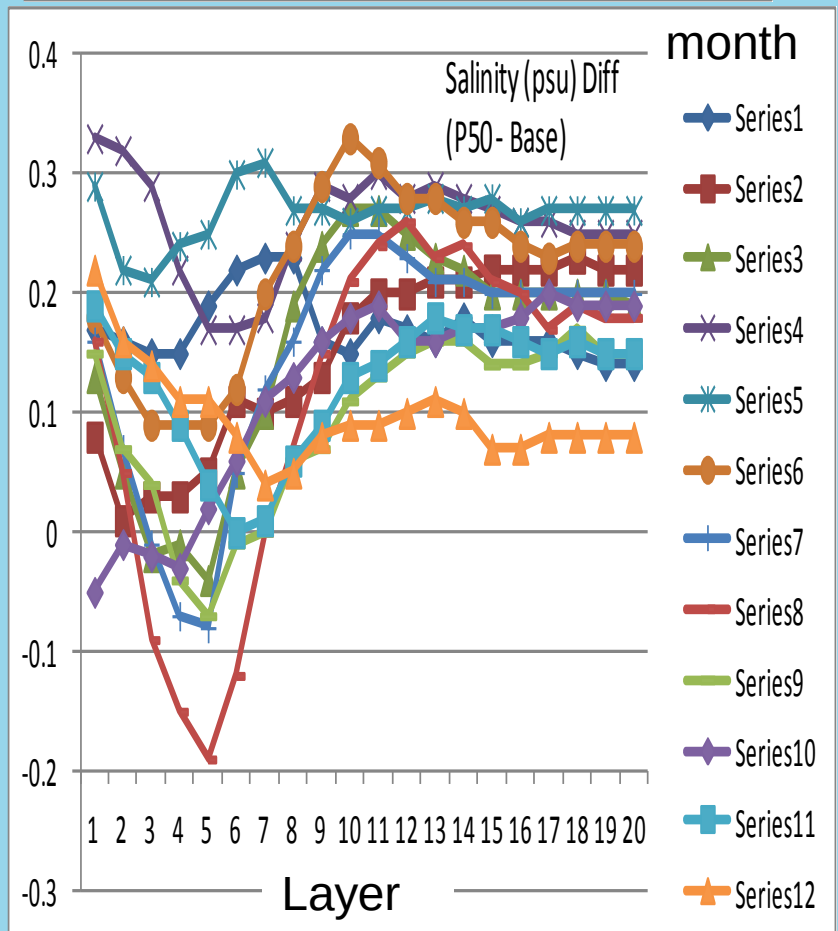
Ratio of Salinity : P50 : Base

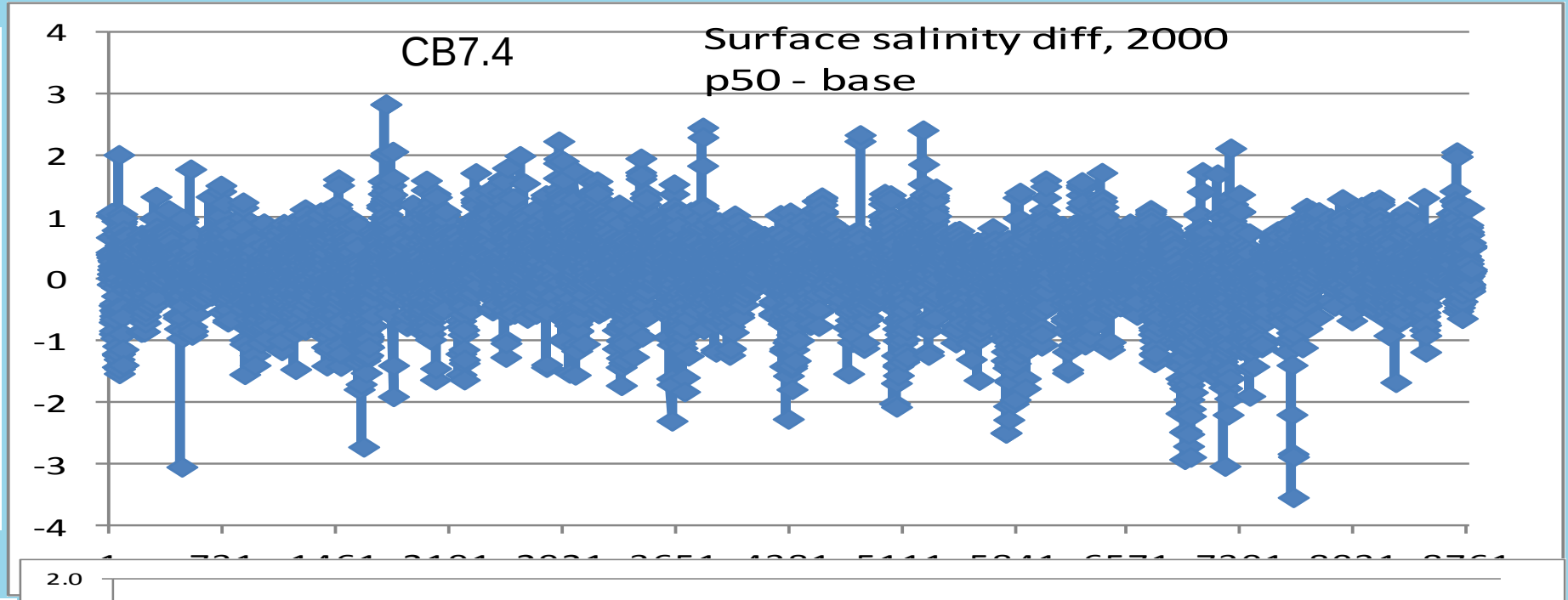


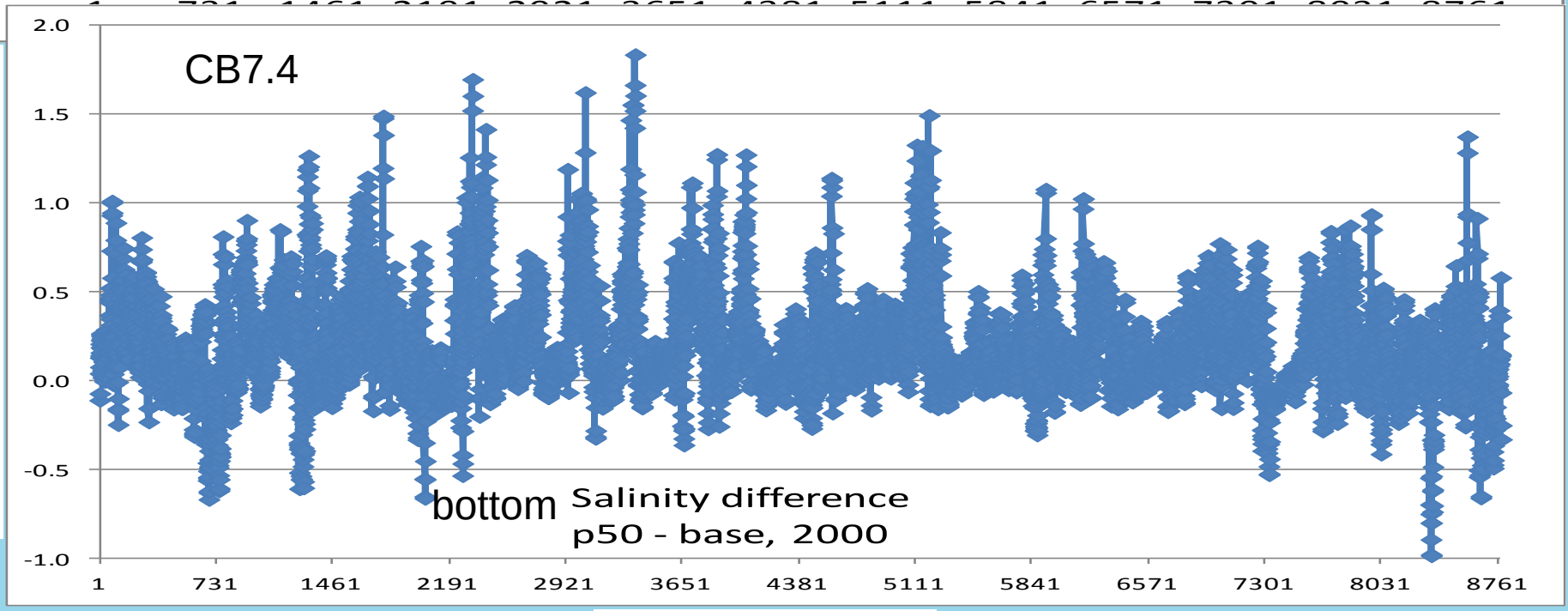
Salinity (psu) Diff (P50 - Base), Shen





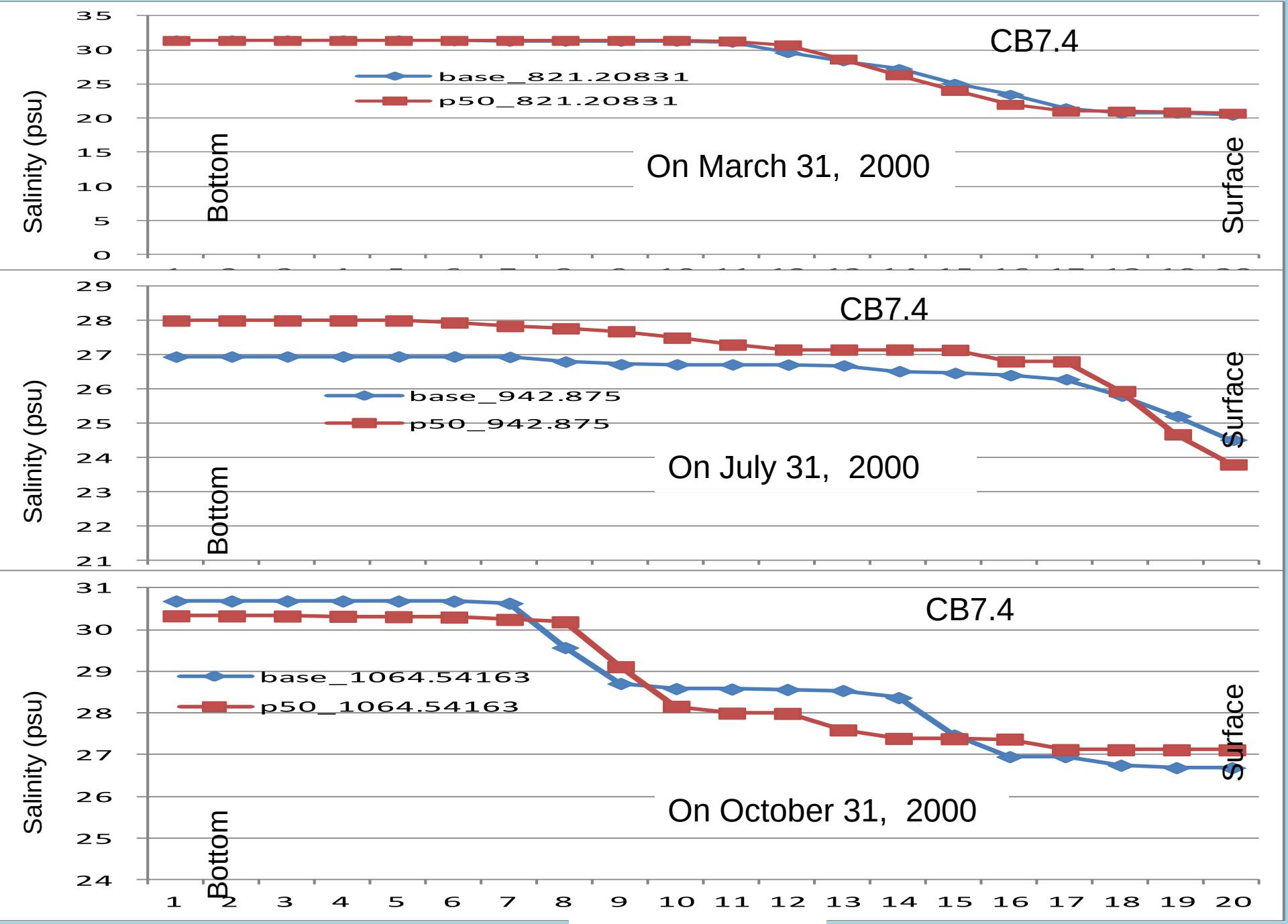




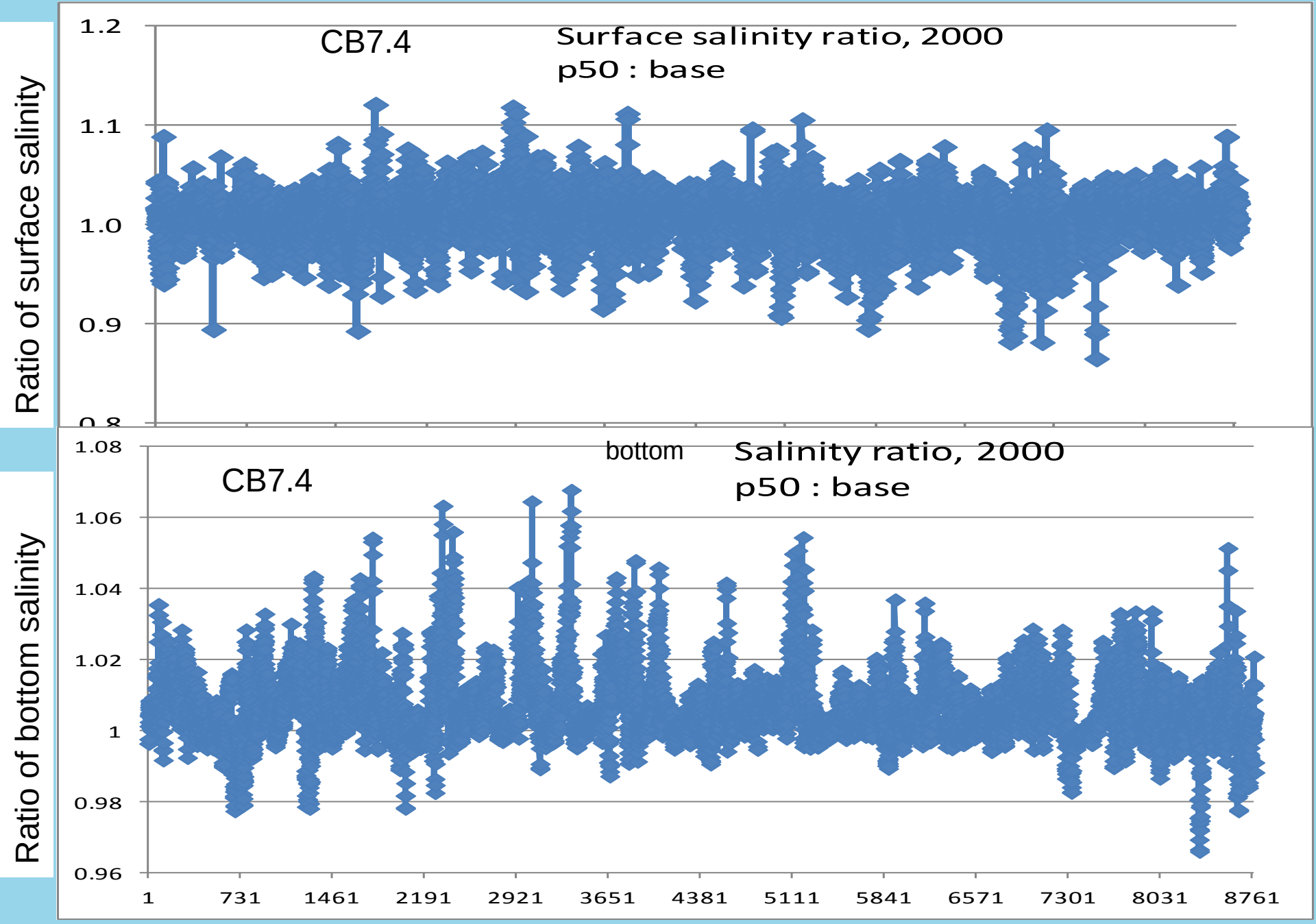


Hours (in 2000

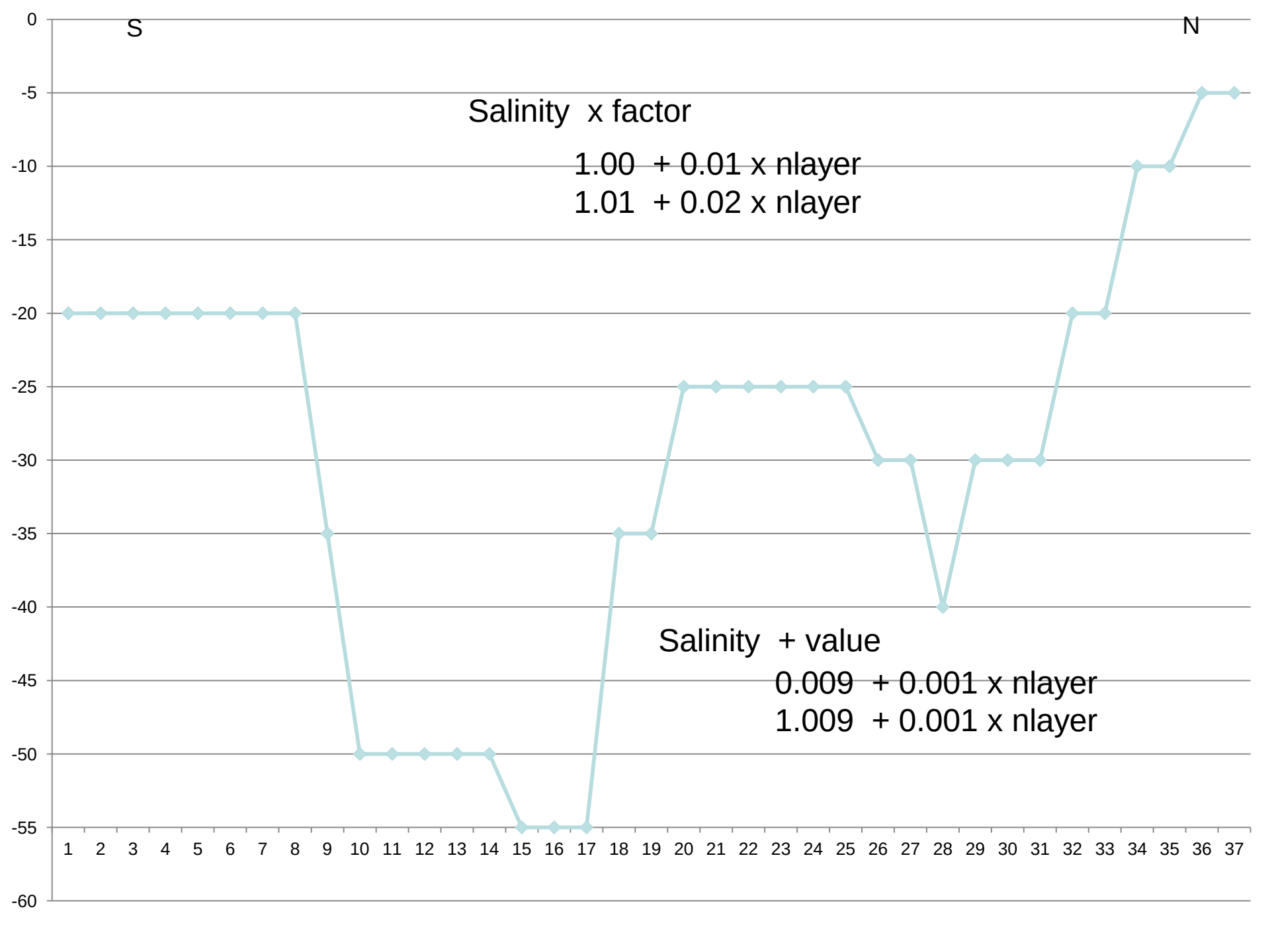
Data provide by Jian Shen

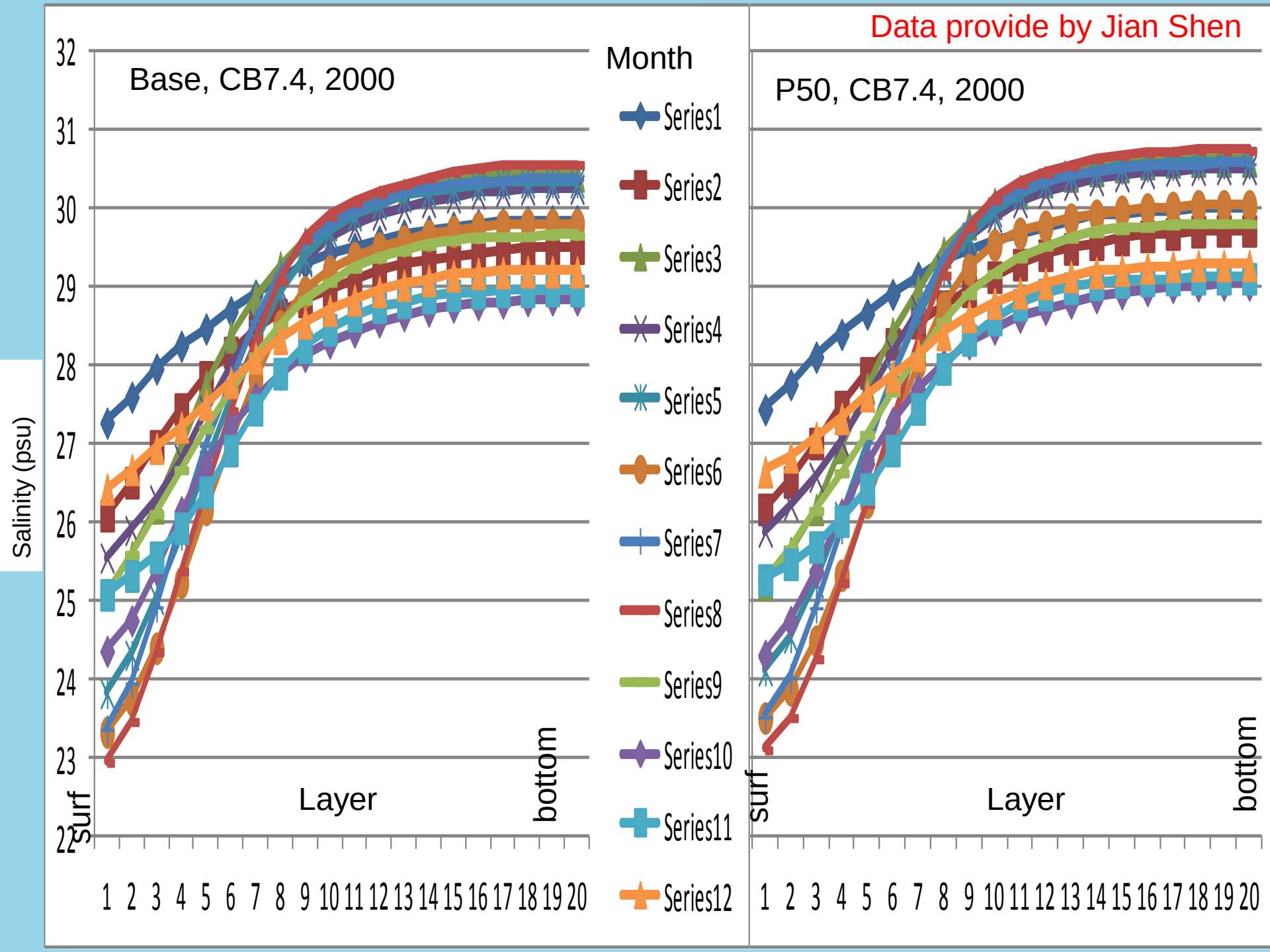


Data provide by Jian Shen

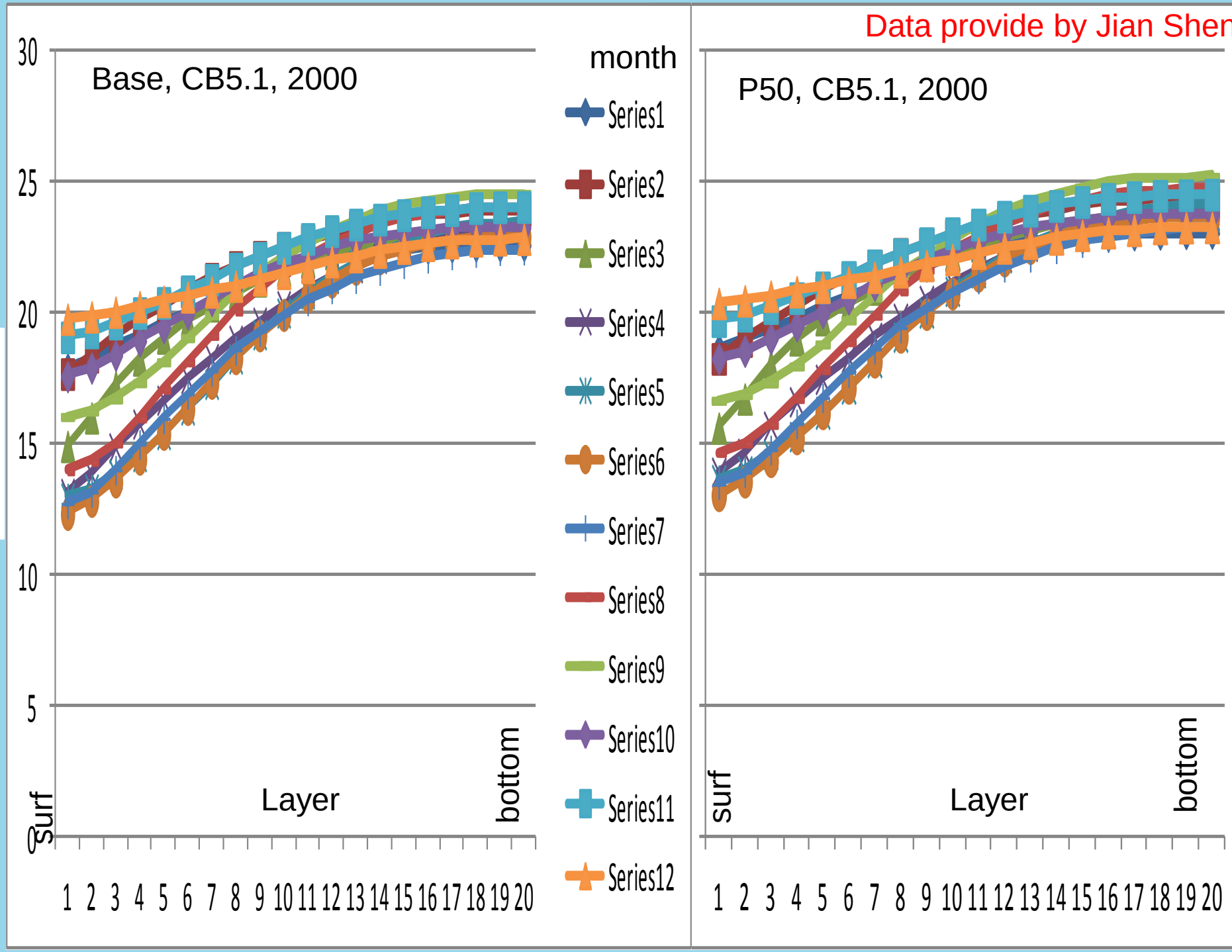


Data provide by Jian Shen


S
N
Salinity x factor
1.00 + 0.01 x nlayer
1.01 + 0.02 x nlayer
Salinity + value
0.009 + 0.001 x nlayer
1.009 + 0.001 x nlayer
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37


Data provide by Jian Shen
Base, CB7.4, 2000
P50, CB7.4, 2000
Salinity (psu)
32
31
30
29
28
27
26
25
24
23
22
surf
bottom
Layer
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Month
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
Series11
Series12

Data provide by Jian Shen



Data provide by Jian Shen