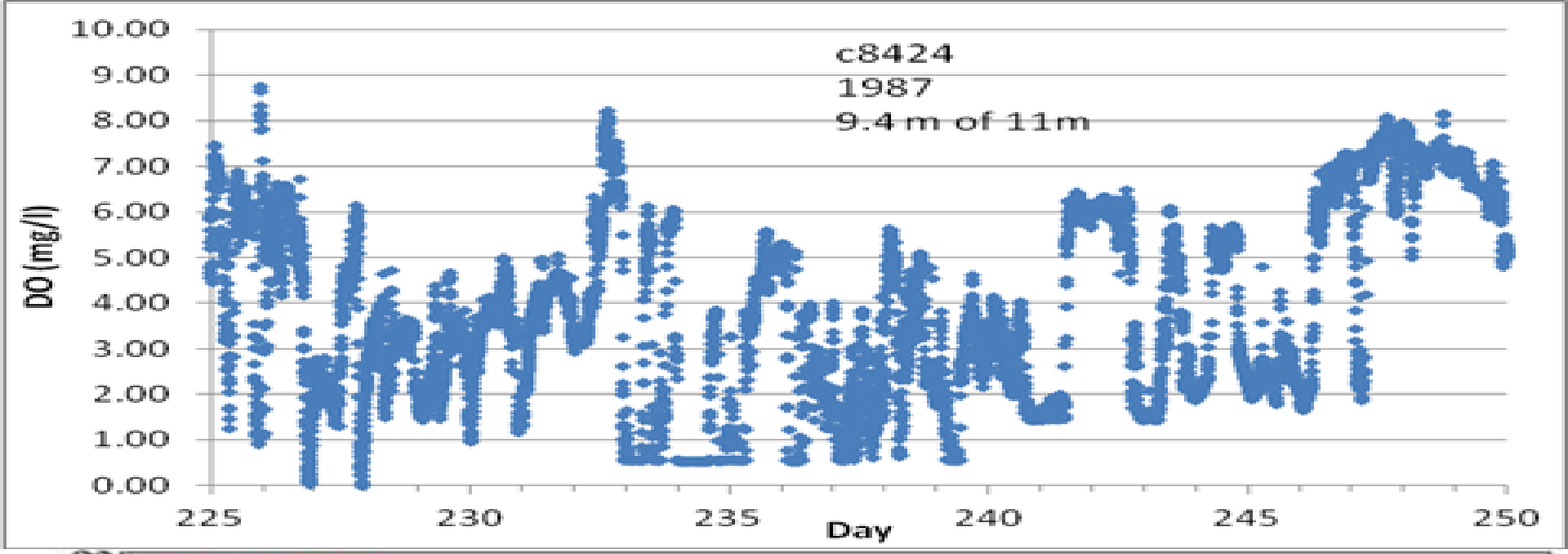
# The Wind Effect on Chesapeake Bay Destratification and Hypoxia

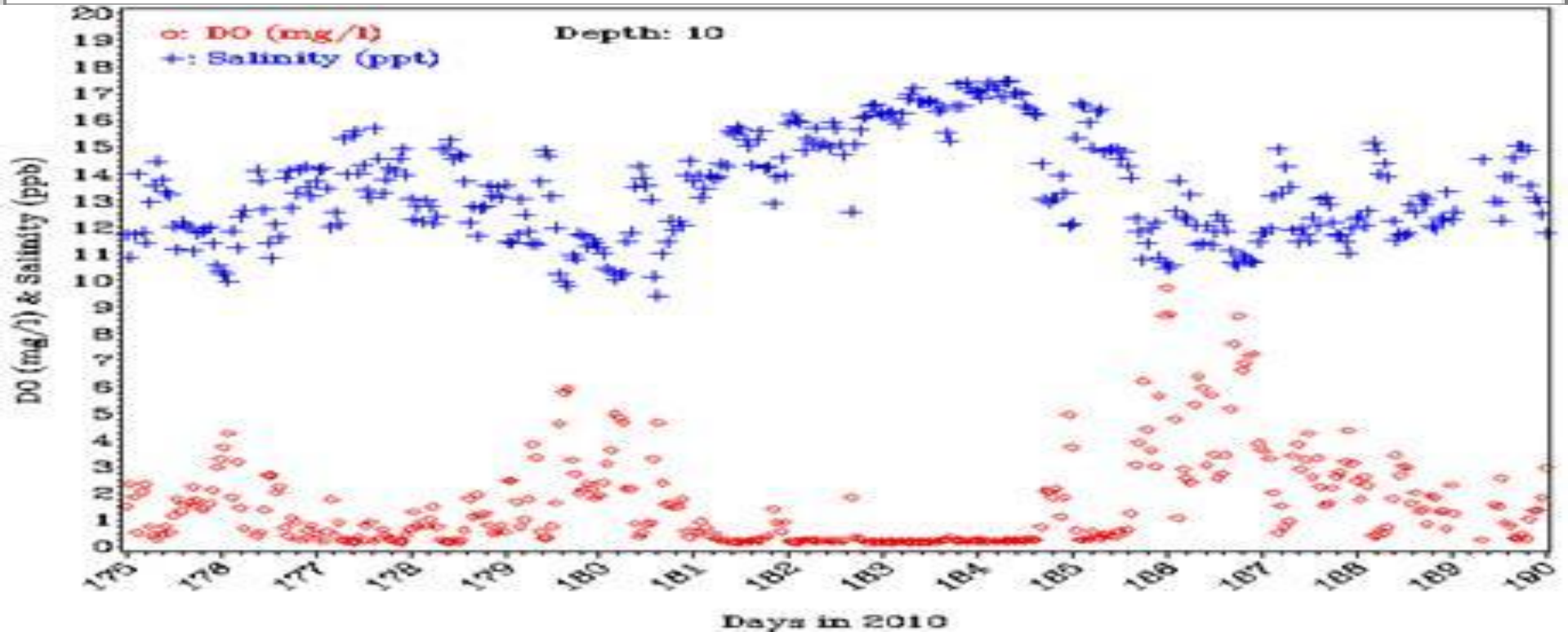
Ping Wang and Harry Wang

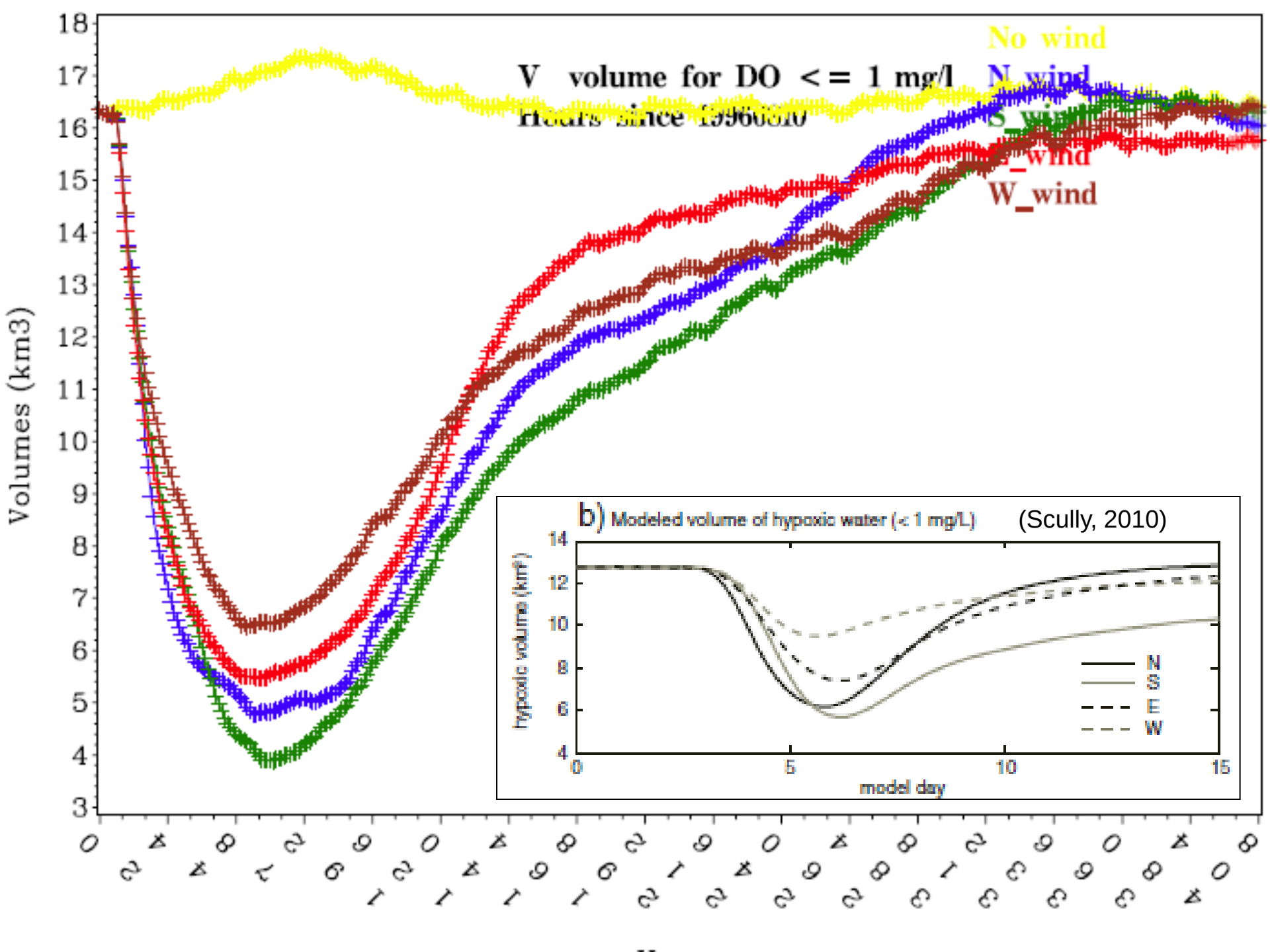
# Introduction

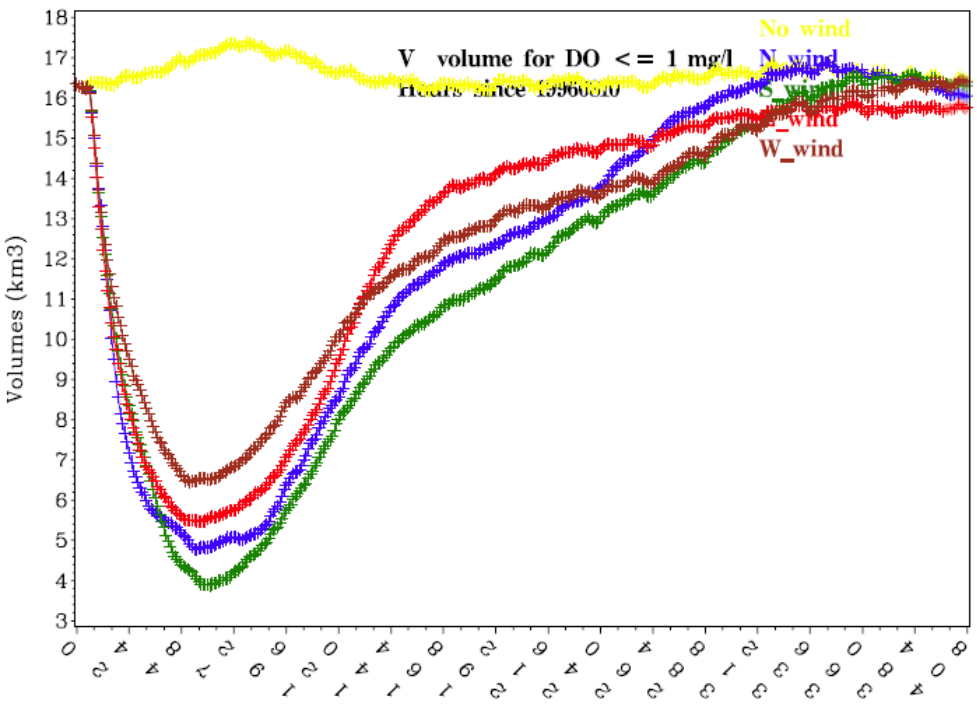
- The effect of wind on circulation and Chesapeake Bay anoxia has been recognized by several researchers; however, different opinions exist on the extents of wind's effect: e.g., the inter-annual variability of hypoxia is mainly controlled by wind or by nutrient loads.

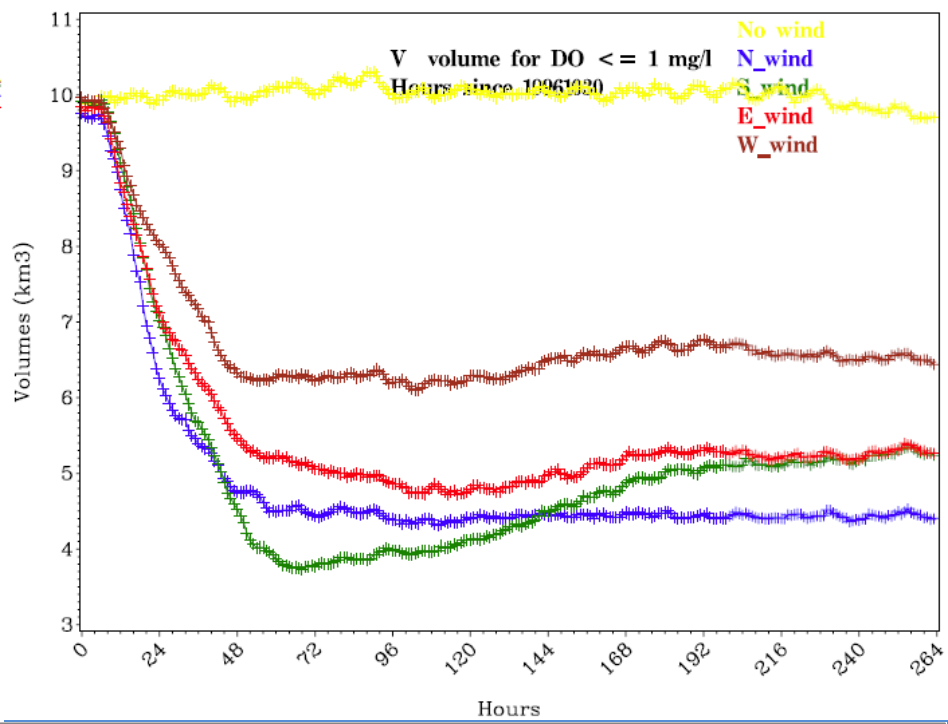
* How do the observed data and the simulations by the Chesapeake Bay regulatory model (i.e., coupled CH3D_hydrodynamic & ICM_WQSTM) indicate the wind effect on hypoxia?

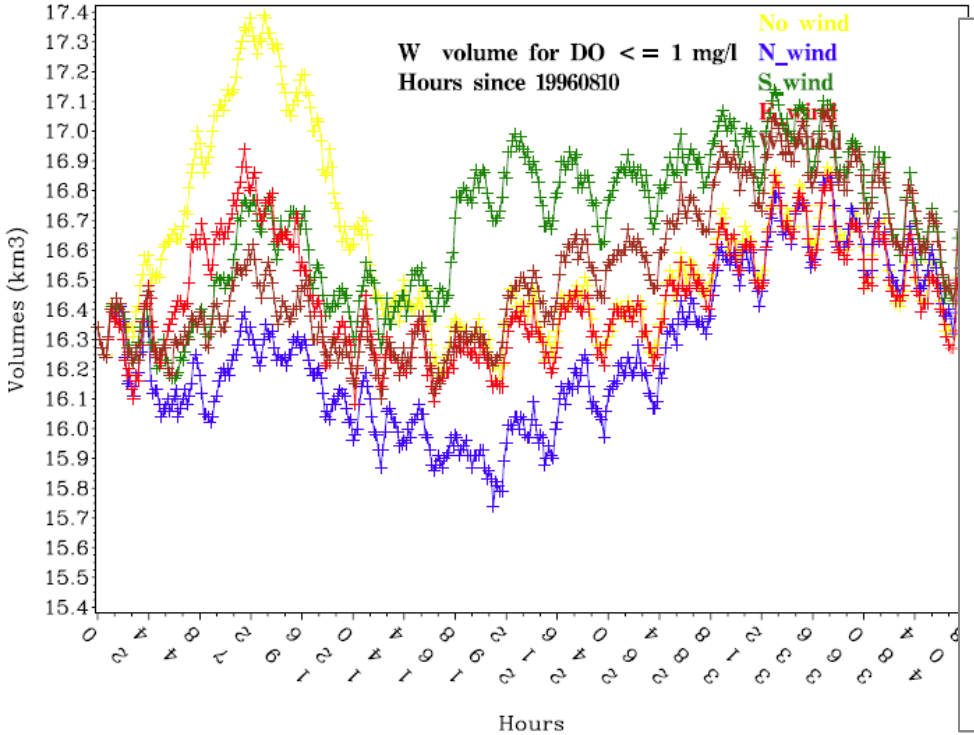

c8424
1987
9.4 m of 11m
DO (mg/l)
Day
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
225
230
235
240
245
250

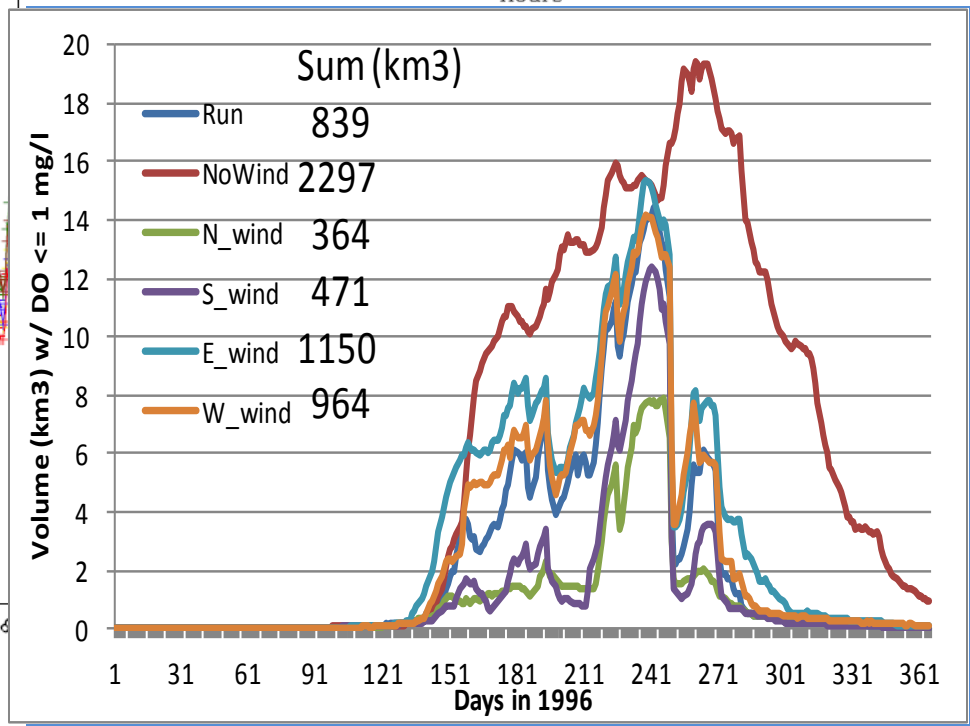

o: DO (mg/l)
+: Salinity (ppt)
Depth: 10
DO (mg/l) & Salinity (ppb)
Days in 2010

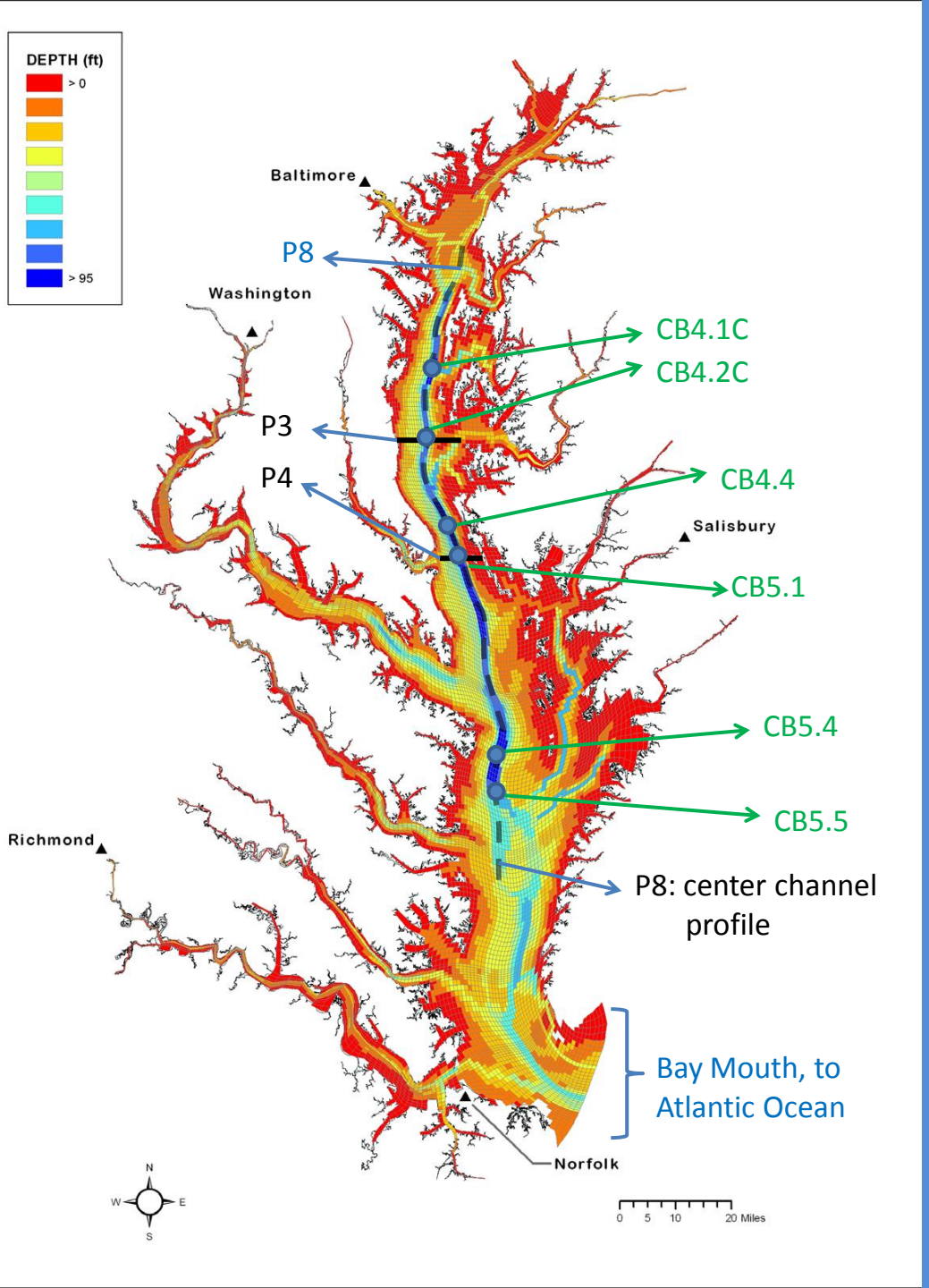

No wind
N_wind
S_wind
E_wind
W_wind
V volume for DO <= 1 mg/l
Volumes (km3)
b) Modeled volume of hypoxic water (< 1 mg/L)
(Scully, 2010)
hypoxic volume (km³)
model day
N
S
E
W

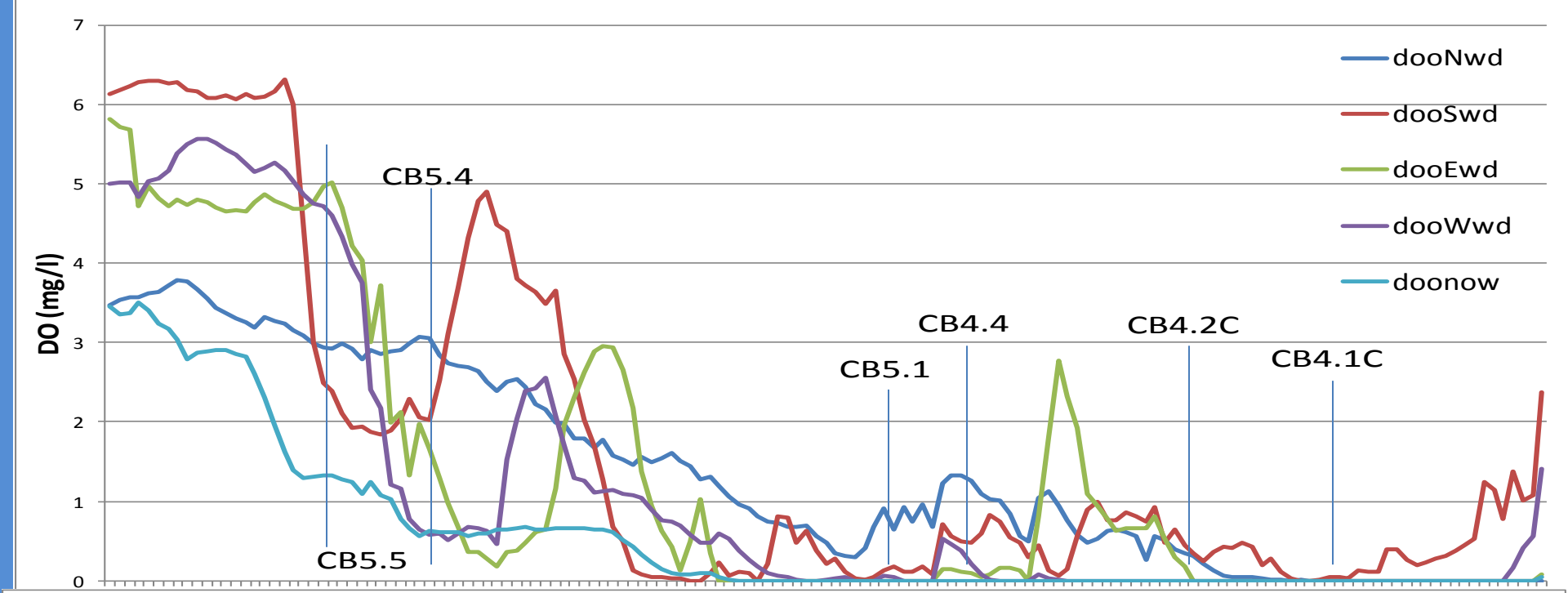

V volume for DO <= 1 mg/l
No wind
N_wind
S_wind
E_wind
W_wind
Volumes (km3)

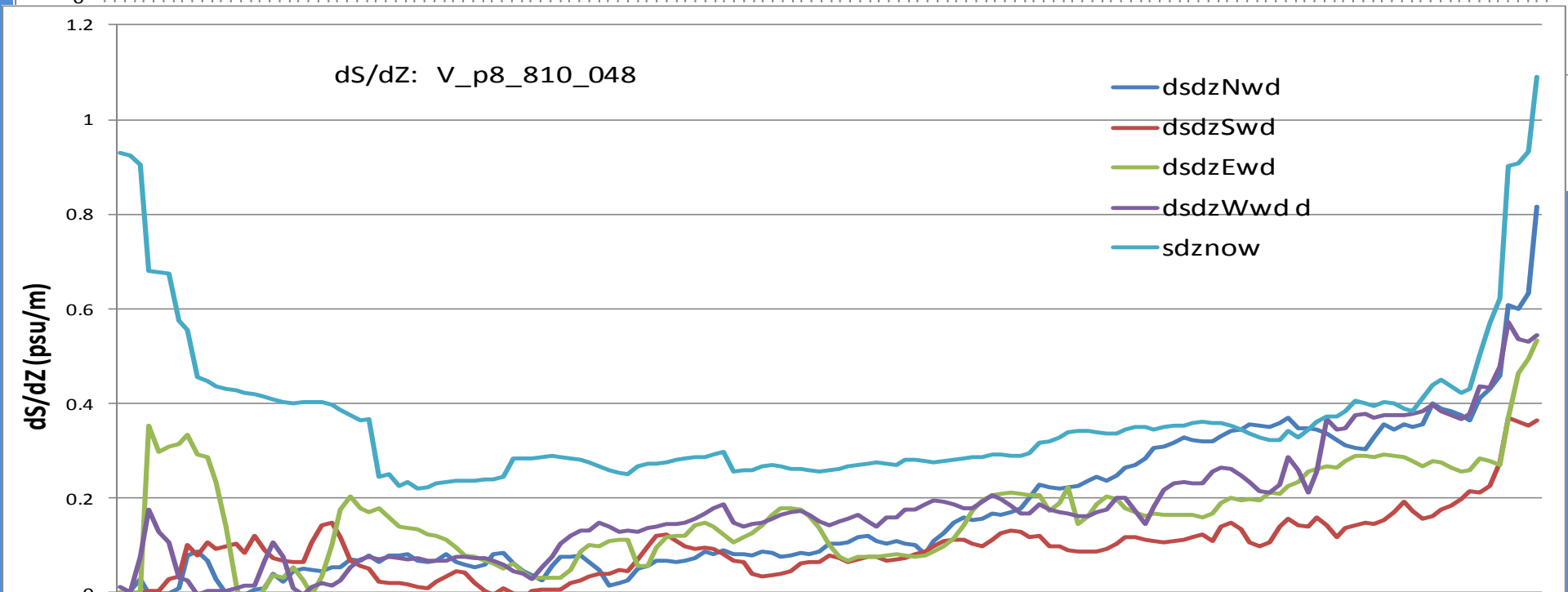

V volume for DO <= 1 mg/l
No wind
N_wind
S_wind
E_wind
W_wind
Volumes (km3)
Hours


W volume for DO <= 1 mg/l
Hours since 19960810
No wind
N_wind
S_wind
E_wind
W_wind
Volumes (km3)
Hours


Sum (km3)
Run 839
NoWind 2297
N_wind 364
S_wind 471
E_wind 1150
W_wind 964
Volume (km3) w/ DO <= 1 mg/l
Days in 1996

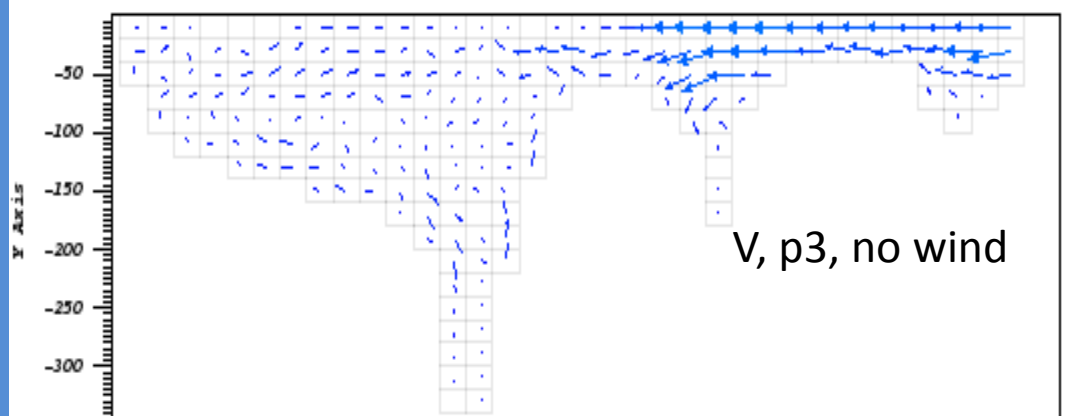

DEPTH (ft)
> 0
> 95
Baltimore
P8
Washington
CB4.1C
CB4.2C
P3
P4
CB4.4
Salisbury
CB5.1
CB5.4
CB5.5
Richmond
P8: center channel profile
Bay Mouth, to Atlantic Ocean
Norfolk
N
W
E
S
0 5 10 20 Miles


DO (mg/l)
7
6
5
4
3
2
1
0
CB5.5
CB5.4
CB5.1
CB4.4
CB4.2C
CB4.1C
dooNwd
dooSwd
dooEwd
dooWwd
doonow

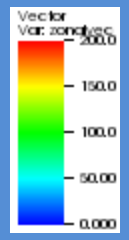

dS/dZ: V_p8_810_048
dS/dZ (psu/m)
1.2
1
0.8
0.6
0.4
0.2
0
dsdzNwd
dsdzSwd
dsdzEwd
dsdzWwd.d
sdznow

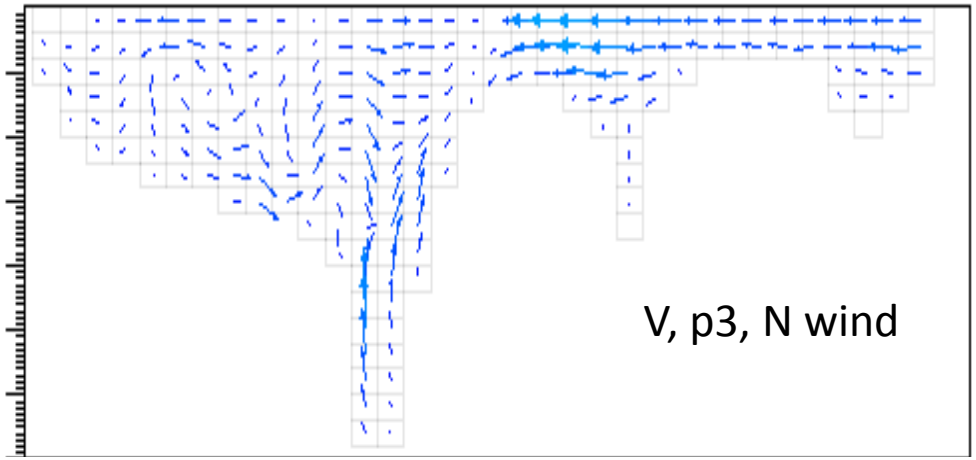
# Wind-induced destratification

- Direct wind mixing: turbulent
- Lateral circulation
- Bathymetry factors
- (Coriolis effect)

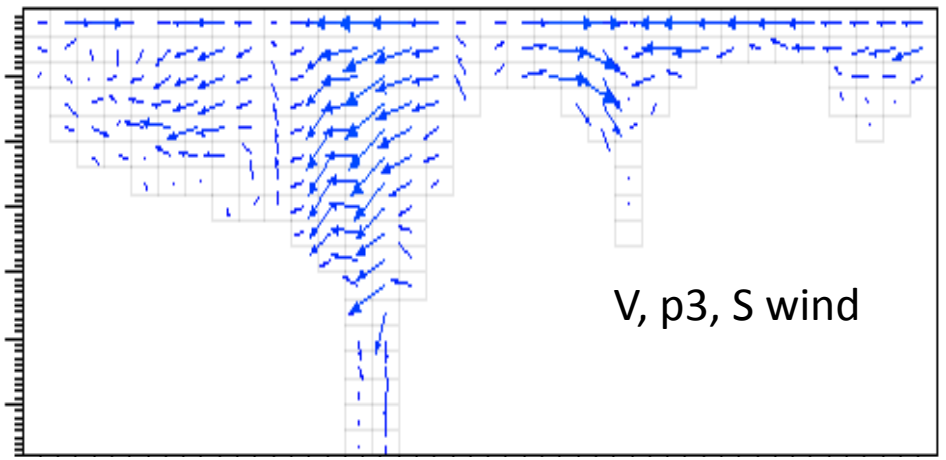



V, p3, no wind

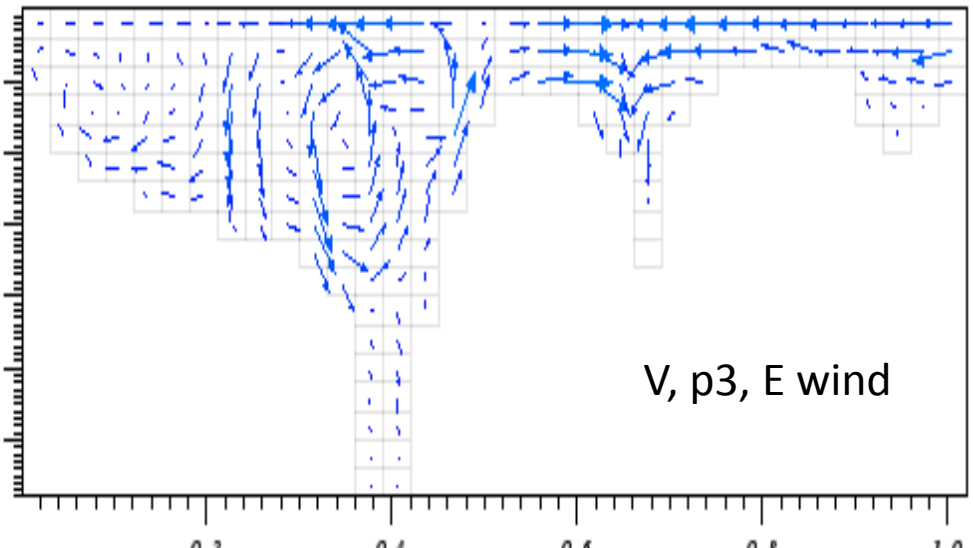


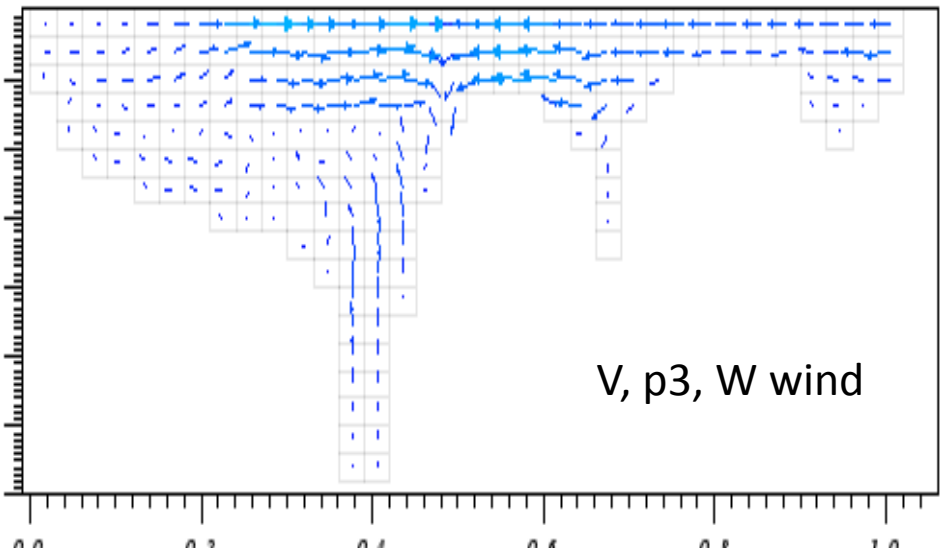
V, p3, N wind



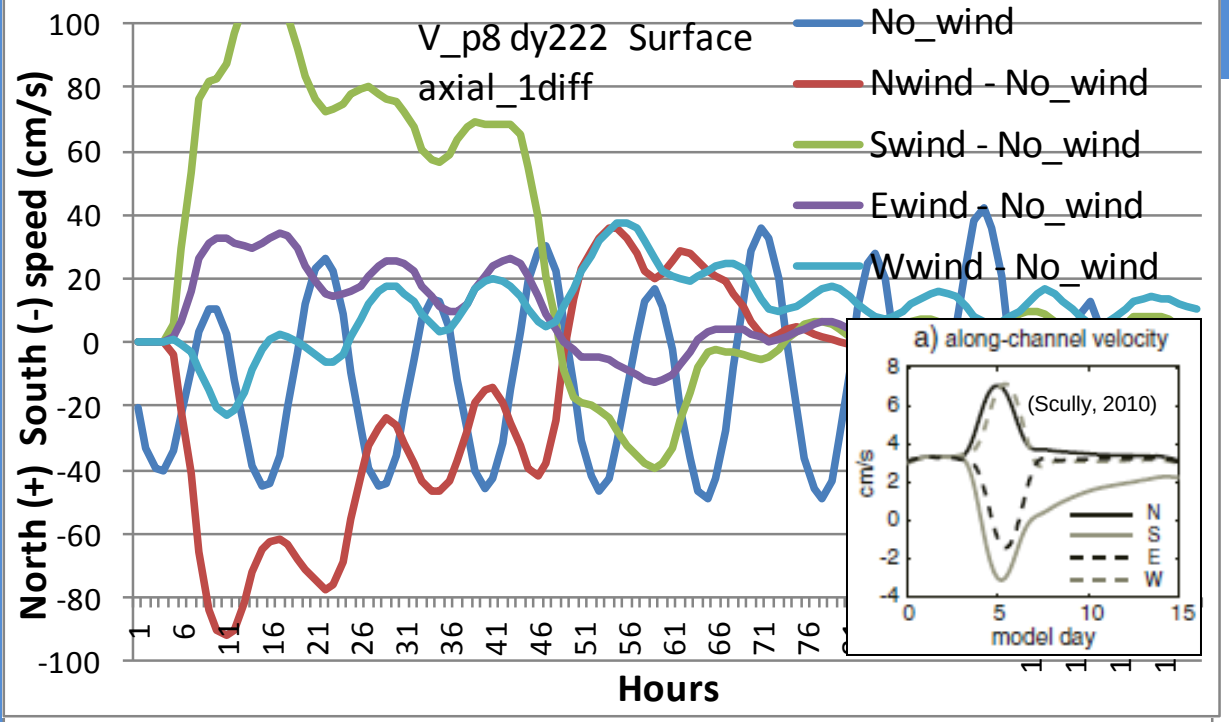
V, p3, S wind

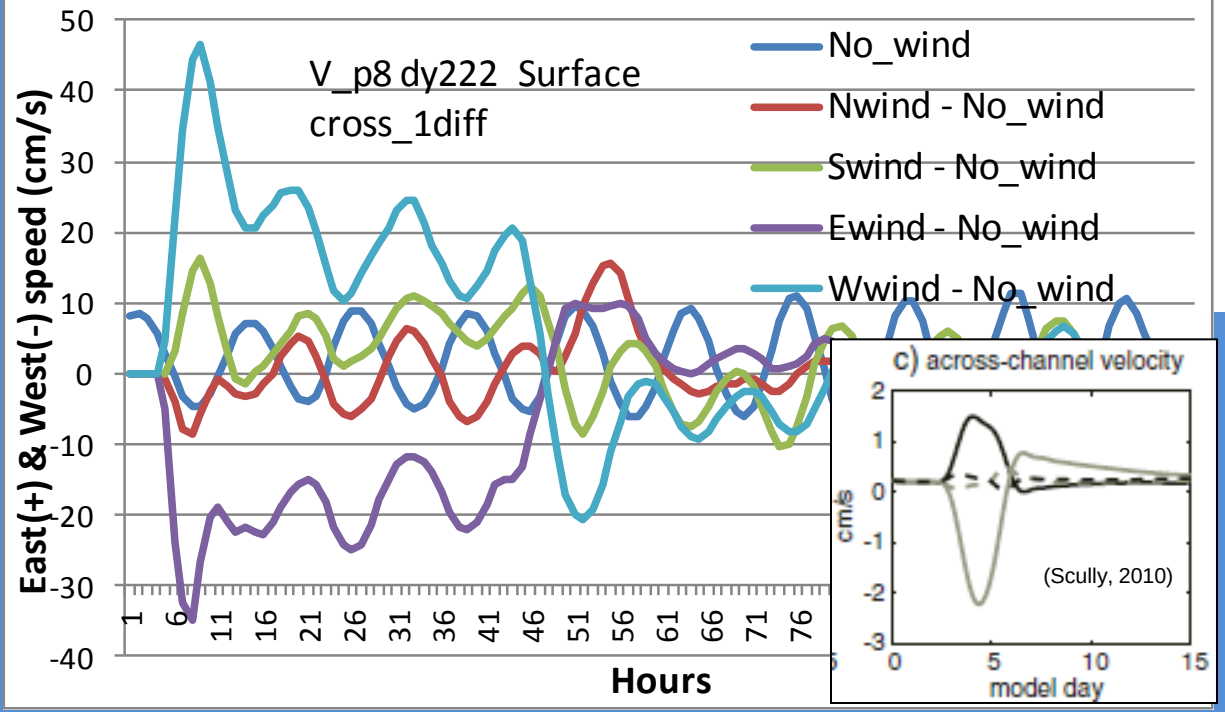


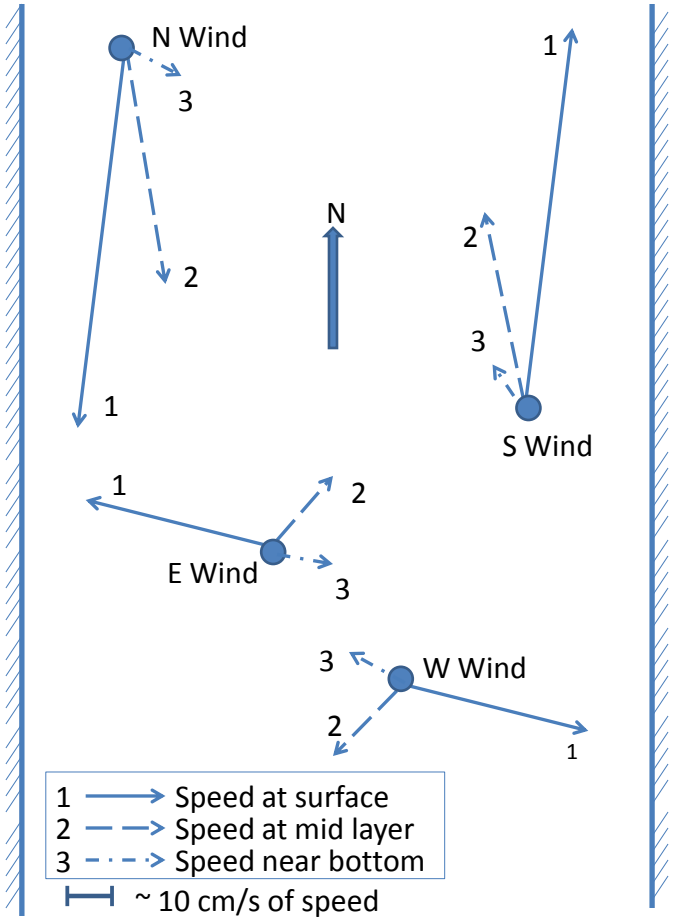
V, p3, E wind



V, p3, W wind

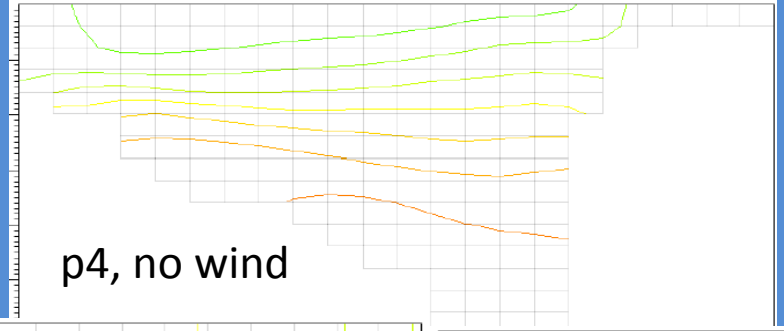


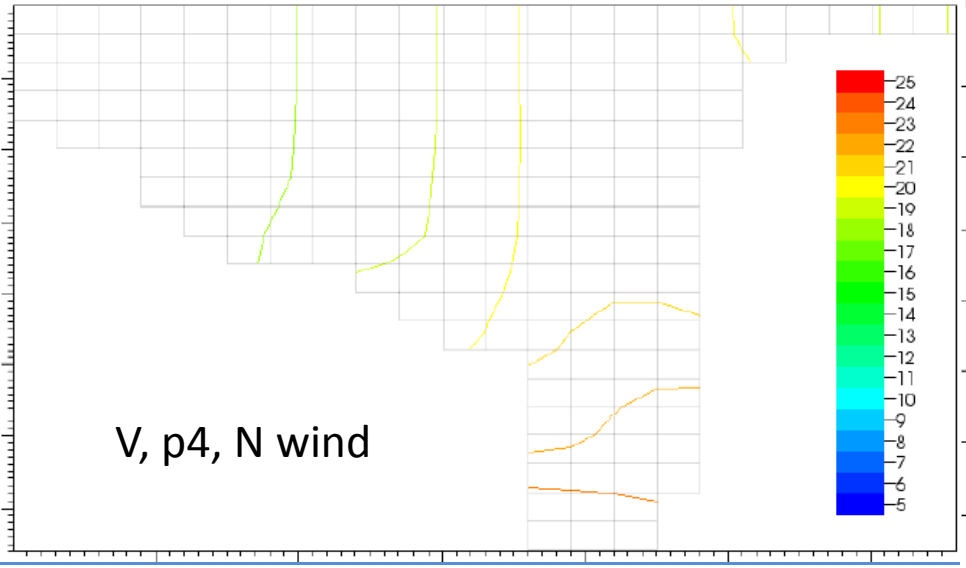



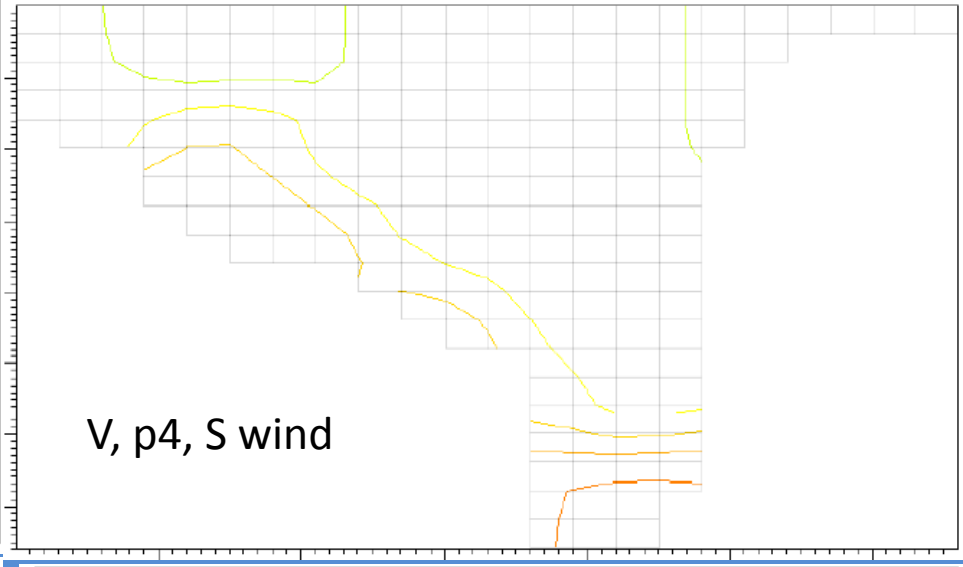



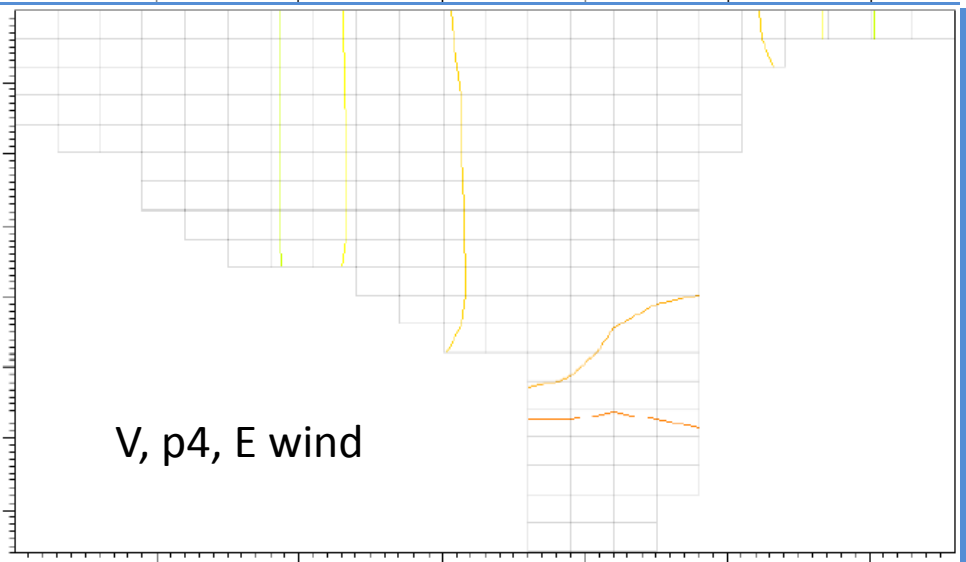

# Coriolis effect on stratified flow

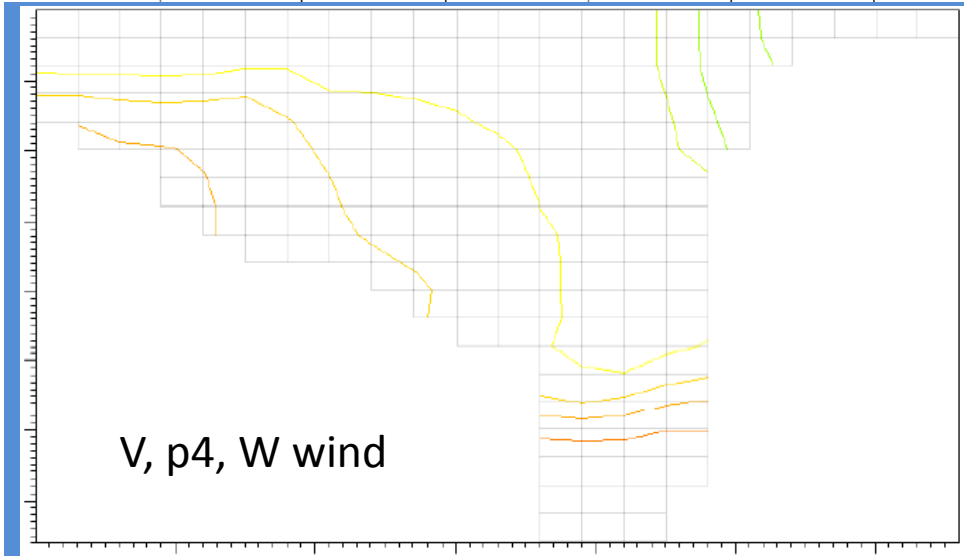
Rossby number Ro = U/f/L
= 0.20/0.00009/20000 = 0.1

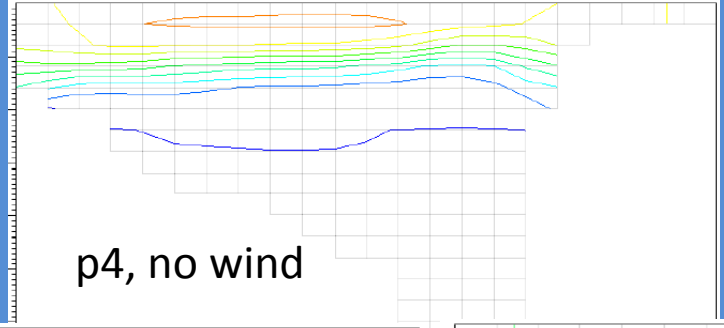

p4, no wind

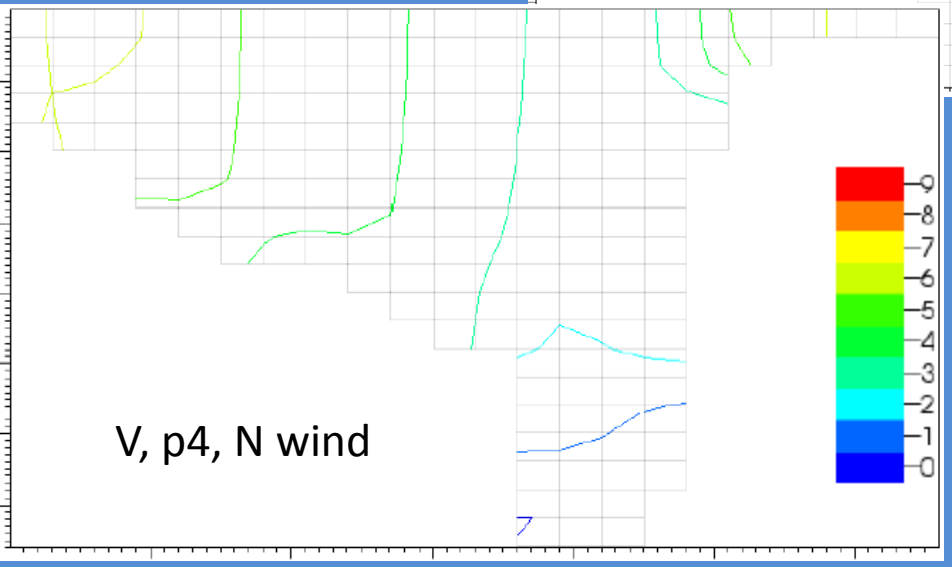

25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
V, p4, N wind

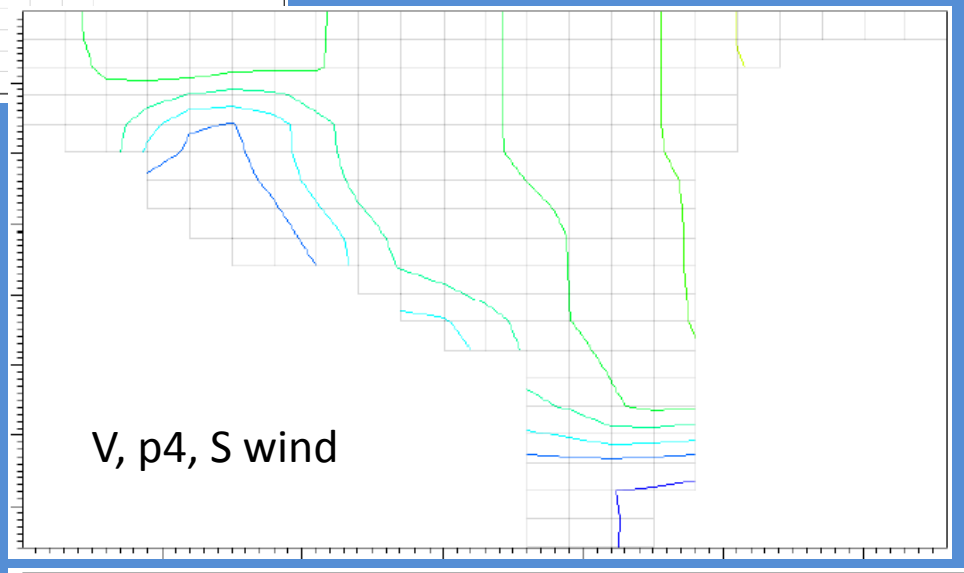

V, p4, S wind

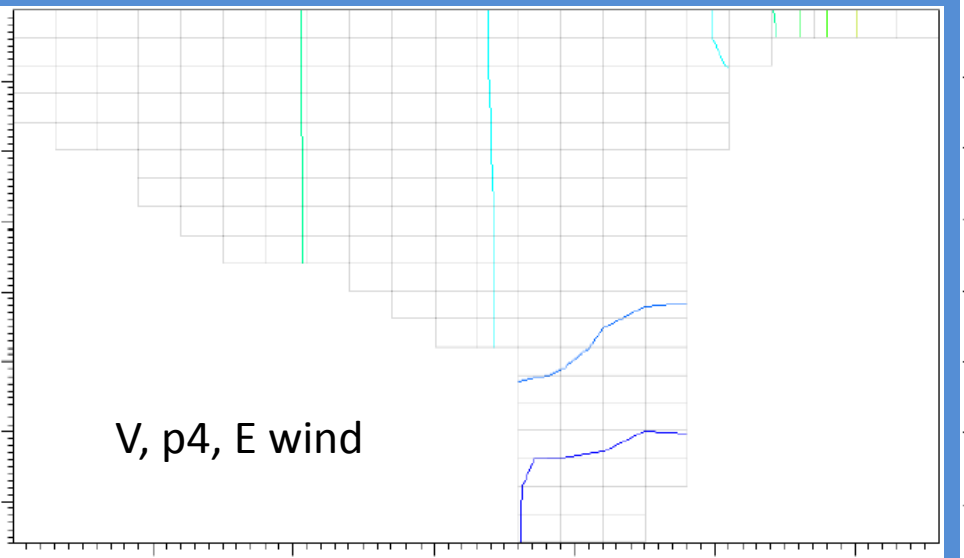

V, p4, E wind

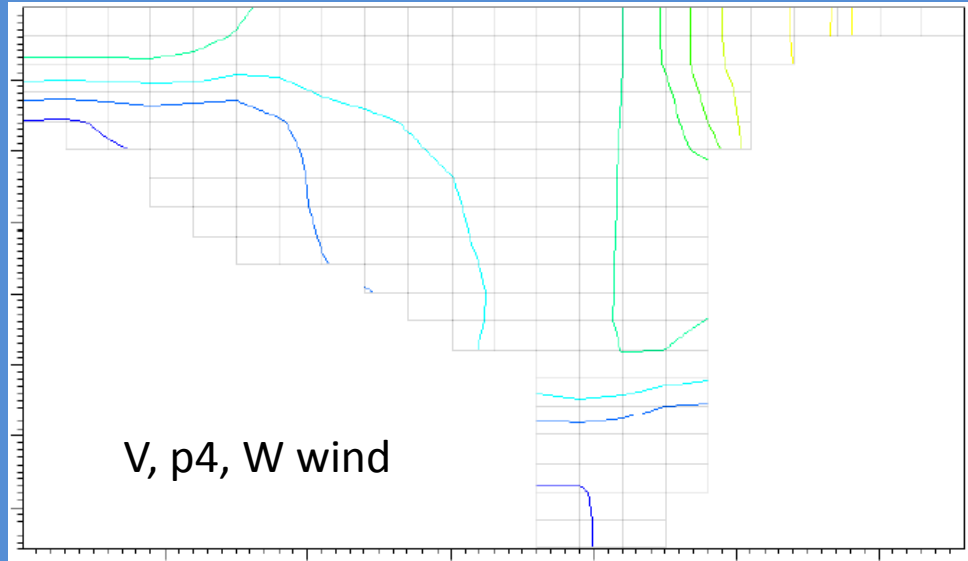

V, p4, W wind

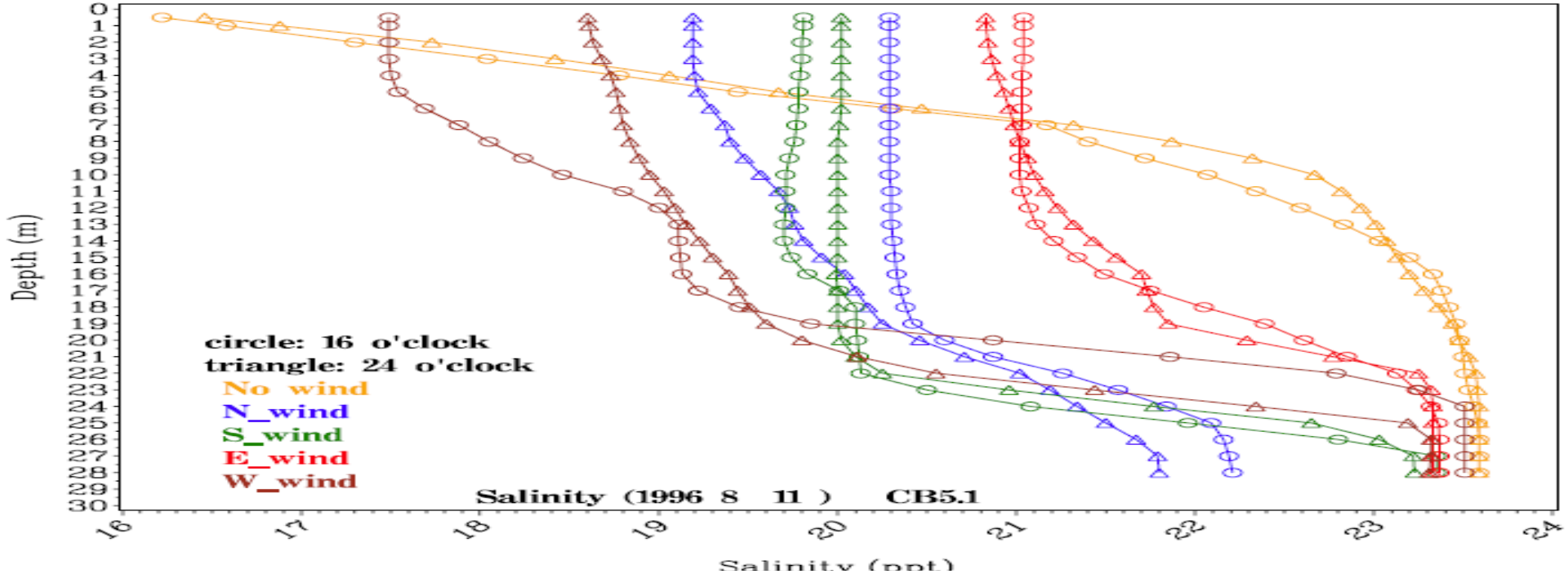

p4, no wind

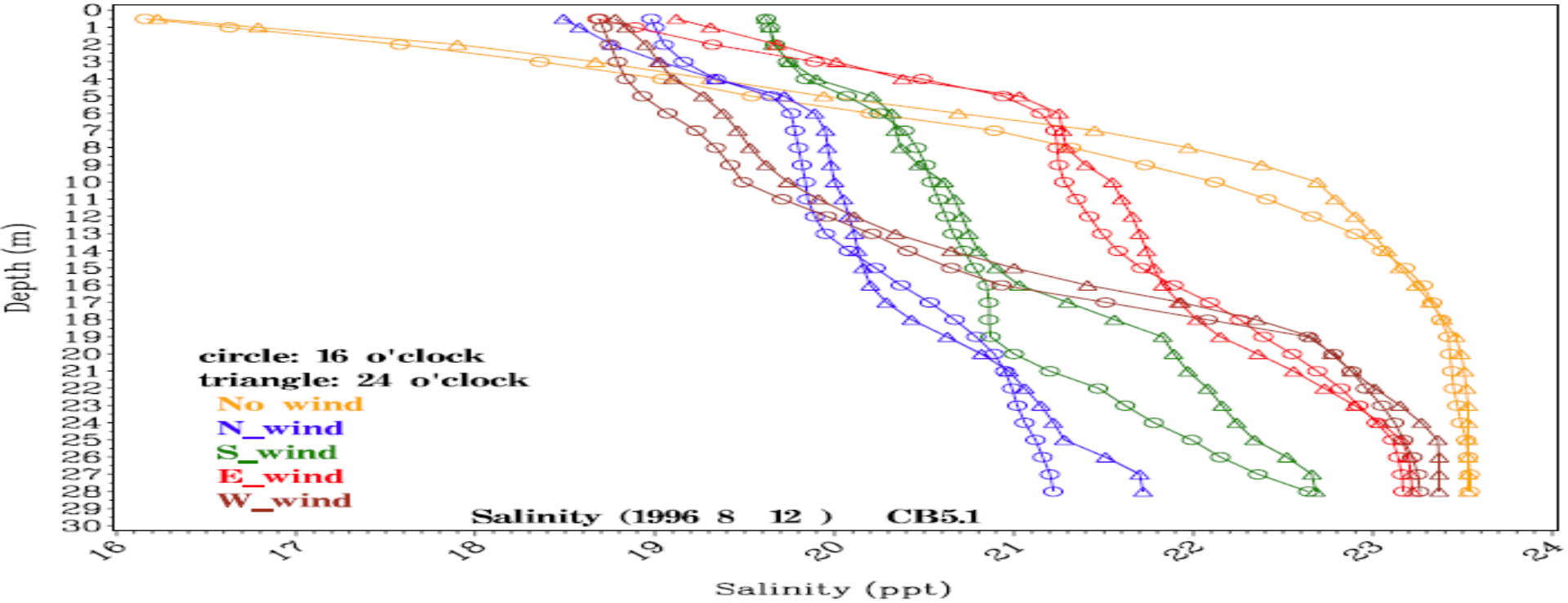

V, p4, N wind
9
8
7
6
5
4
3
2
1
0

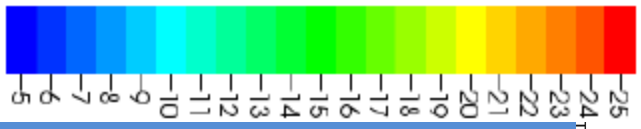

V, p4, S wind


V, p4, E wind


V, p4, W wind


Depth (m)
circle: 16 o'clock
triangle: 24 o'clock
No wind
N_wind
S_wind
E_wind
W_wind
Salinity (1996 8 11 ) CB5.1
Salinity (ppt)


Depth (m)
circle: 16 o'clock
triangle: 24 o'clock
No wind
N_wind
S_wind
E_wind
W_wind
Salinity (1996 8 12 ) CB5.1
Salinity (ppt)



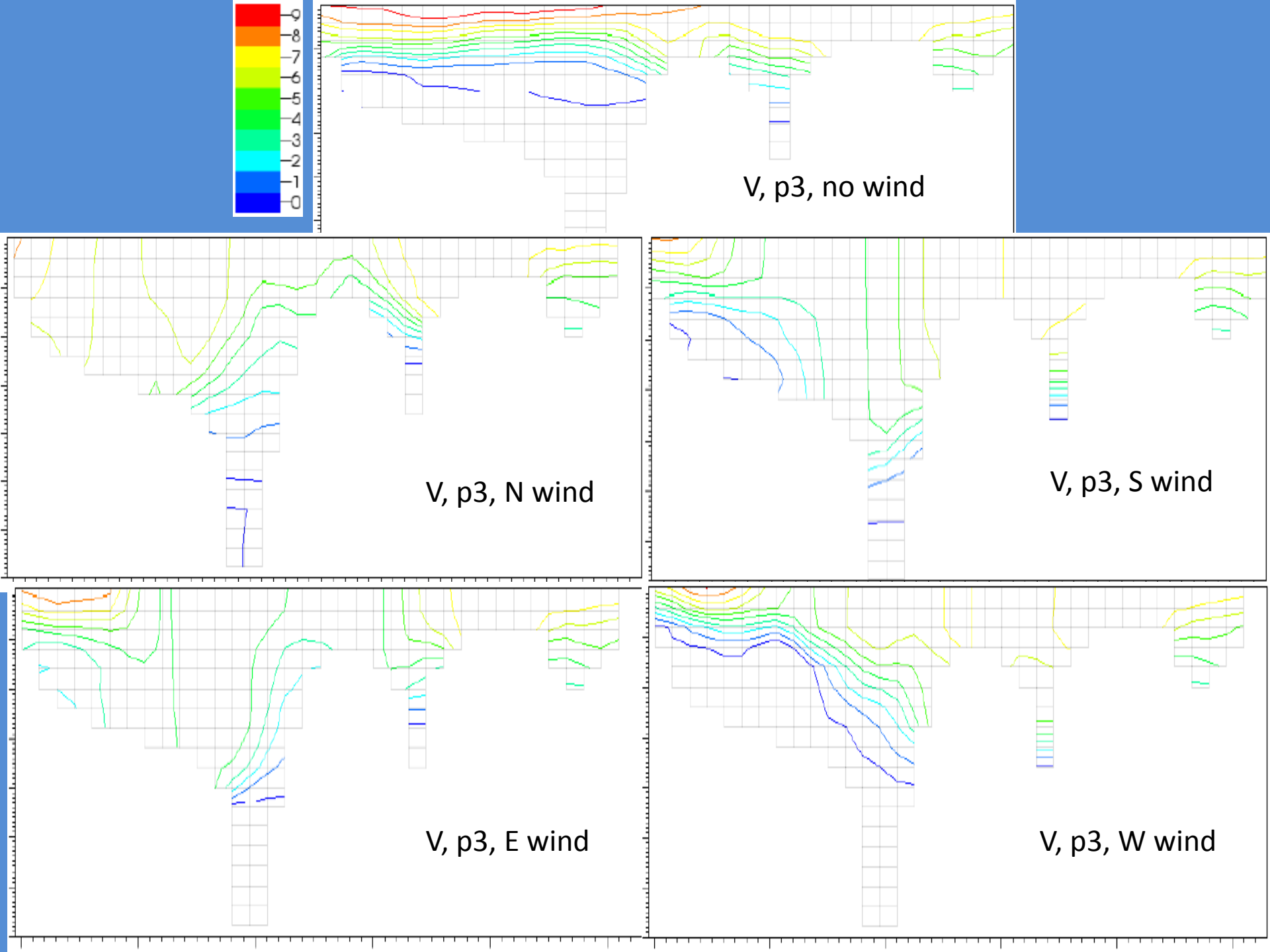

V, p3, no wind

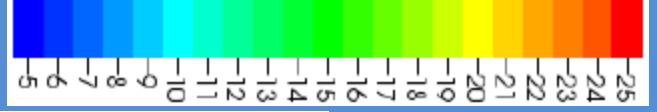
V, p3, N wind

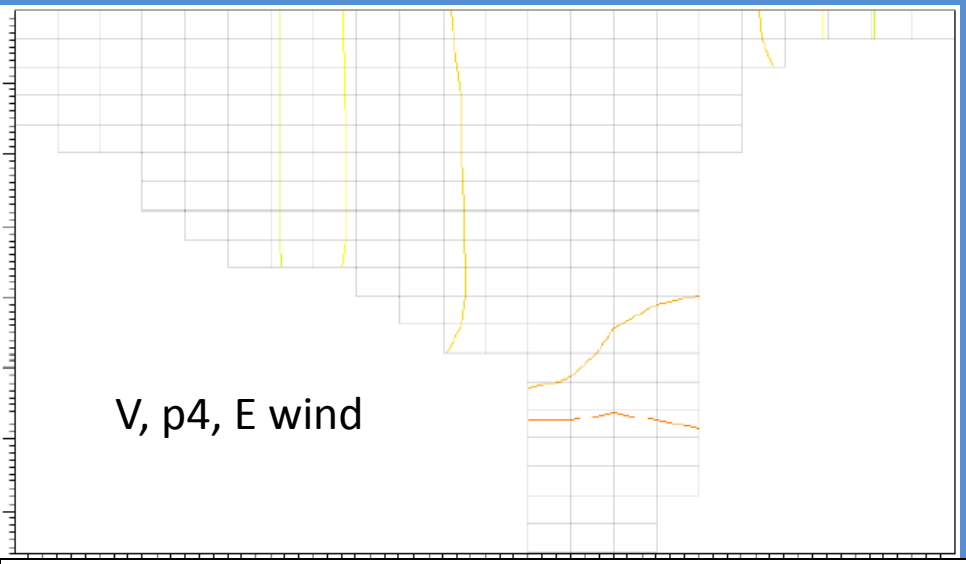
V, p3, S wind

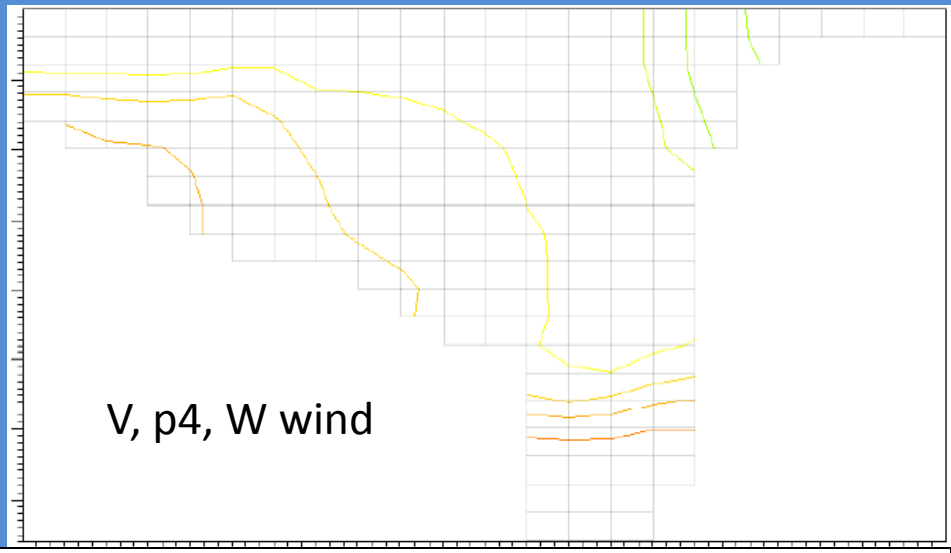
V, p3, E wind

V, p3, W wind

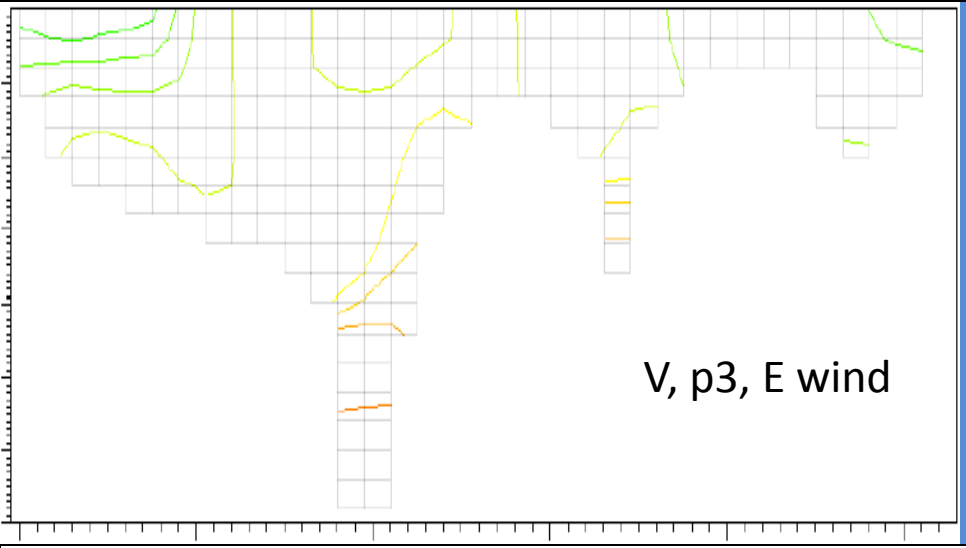

9
8
7
6
5
4
3
2
1
0
V, p3, no wind
V, p3, N wind
V, p3, S wind
V, p3, E wind
V, p3, W wind

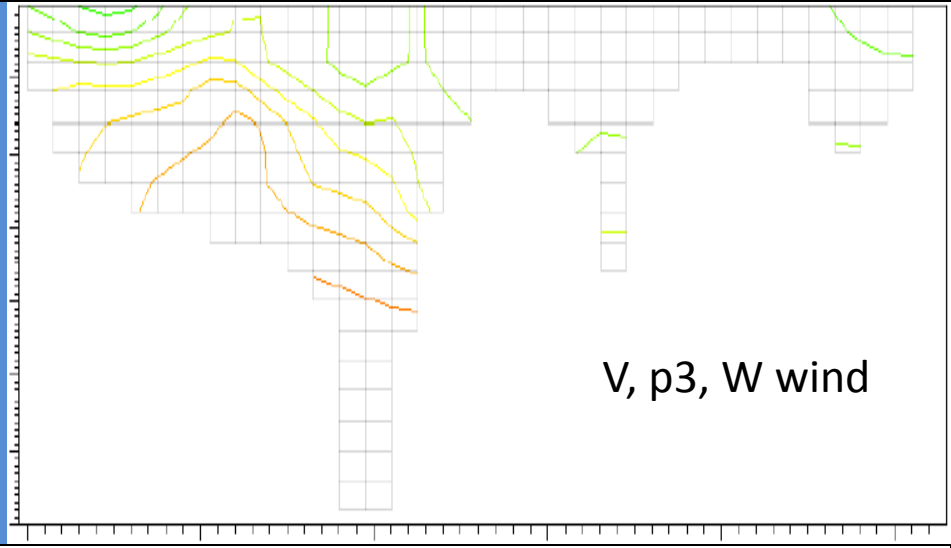


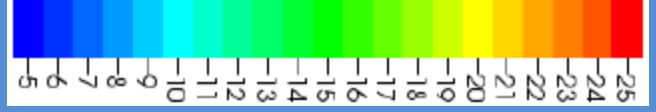



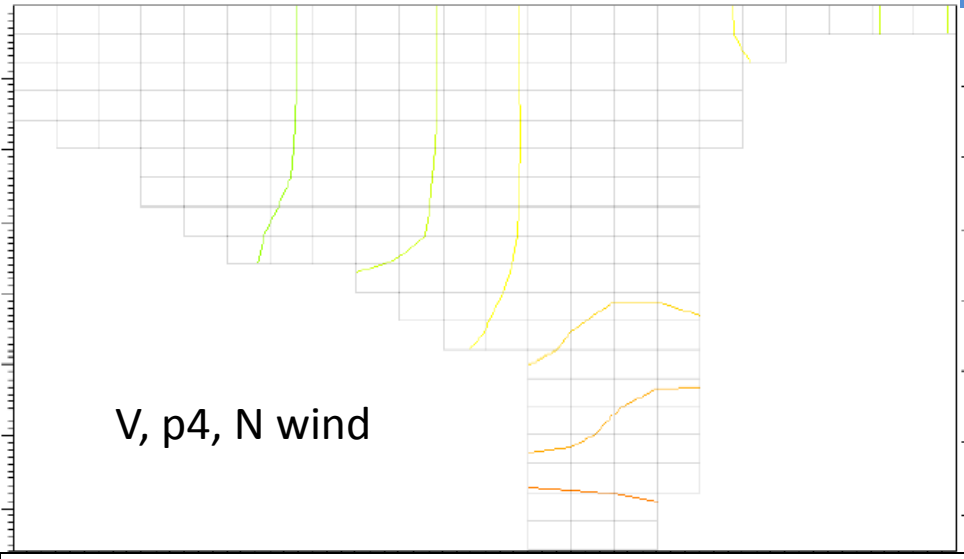

The flatter and wider east shoal in p3 than p4 causes less destratification by winds in p3 than in p4.

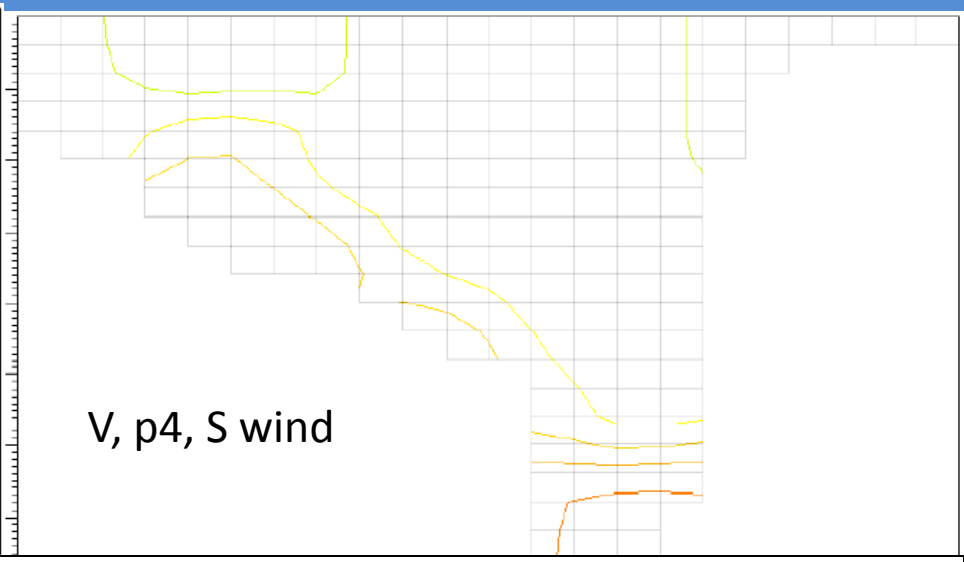


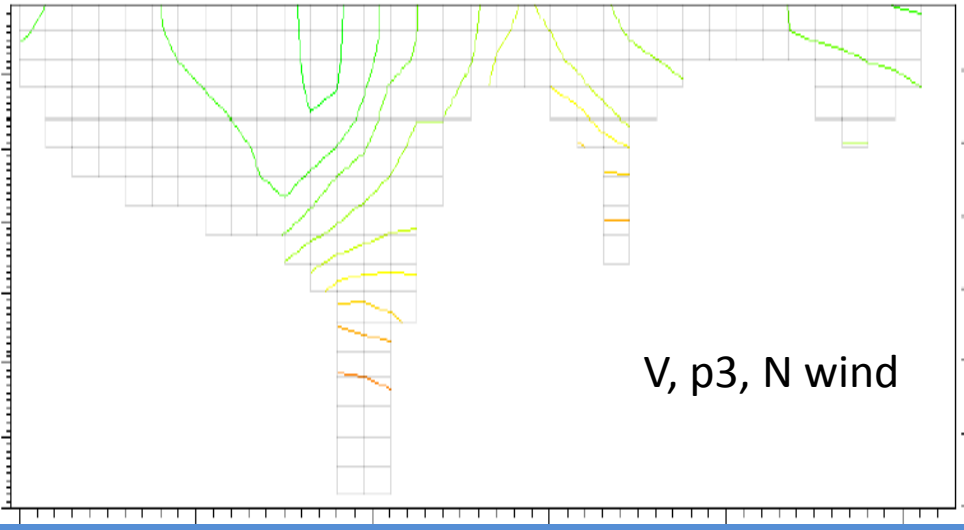

The steeper east wall than west wall of channel in both p3 and p4 favors destratifucation by east wind over west wind in both locations.

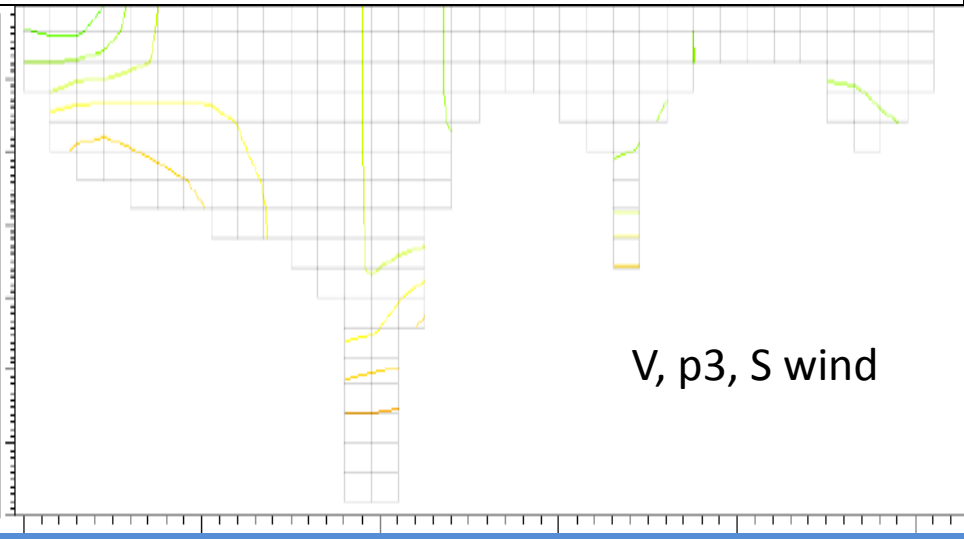


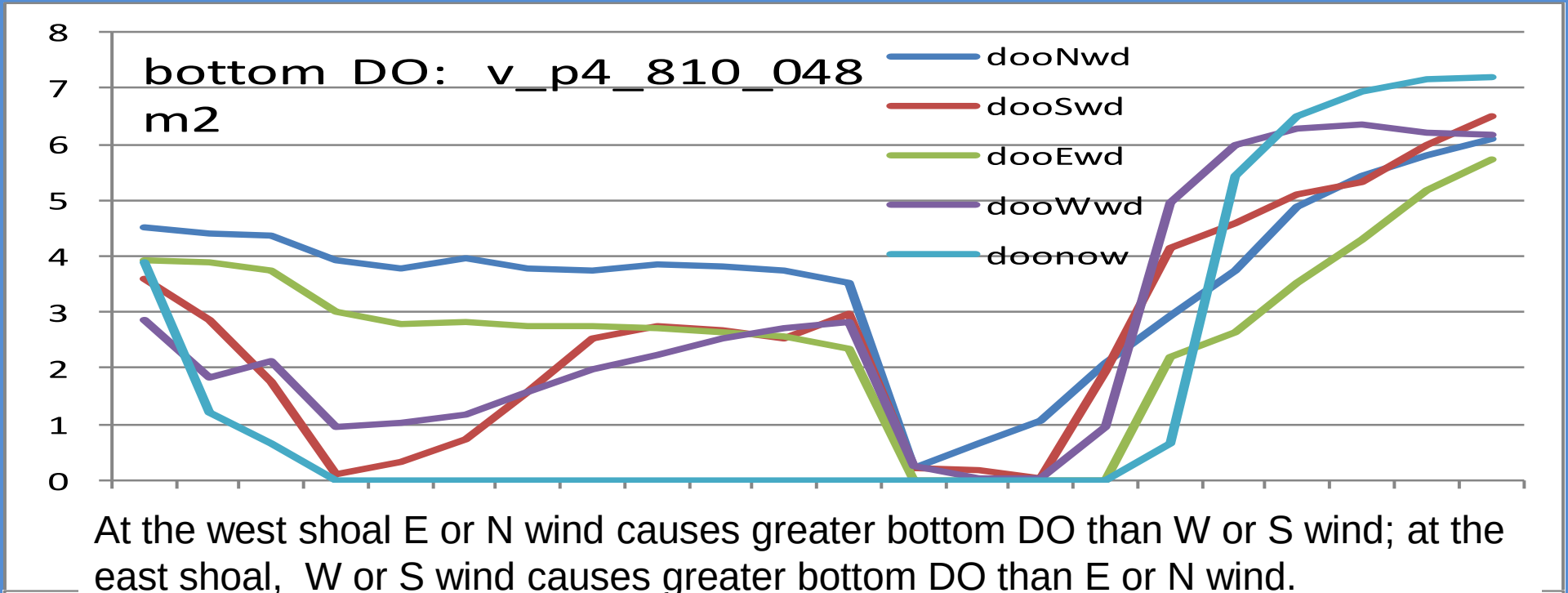




The flatter and wider east shoal in p3 than p4 causes less destratification by winds in p3 than in p4.

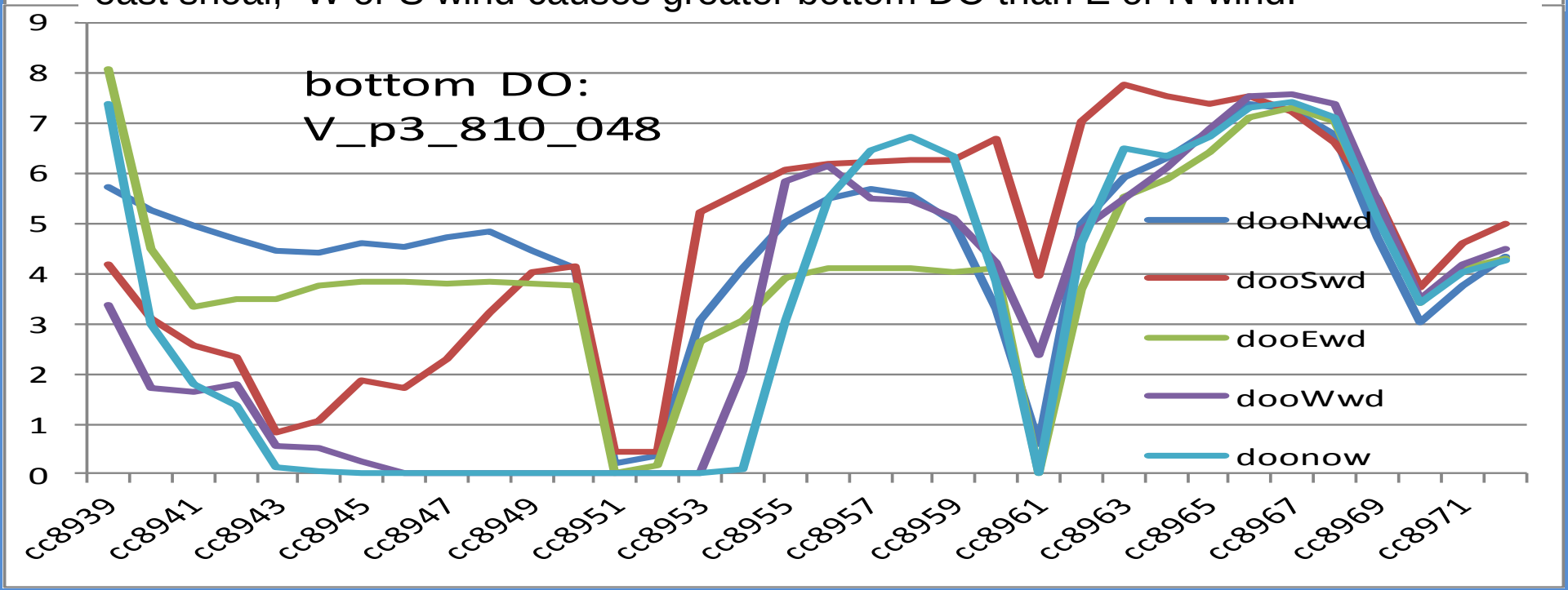


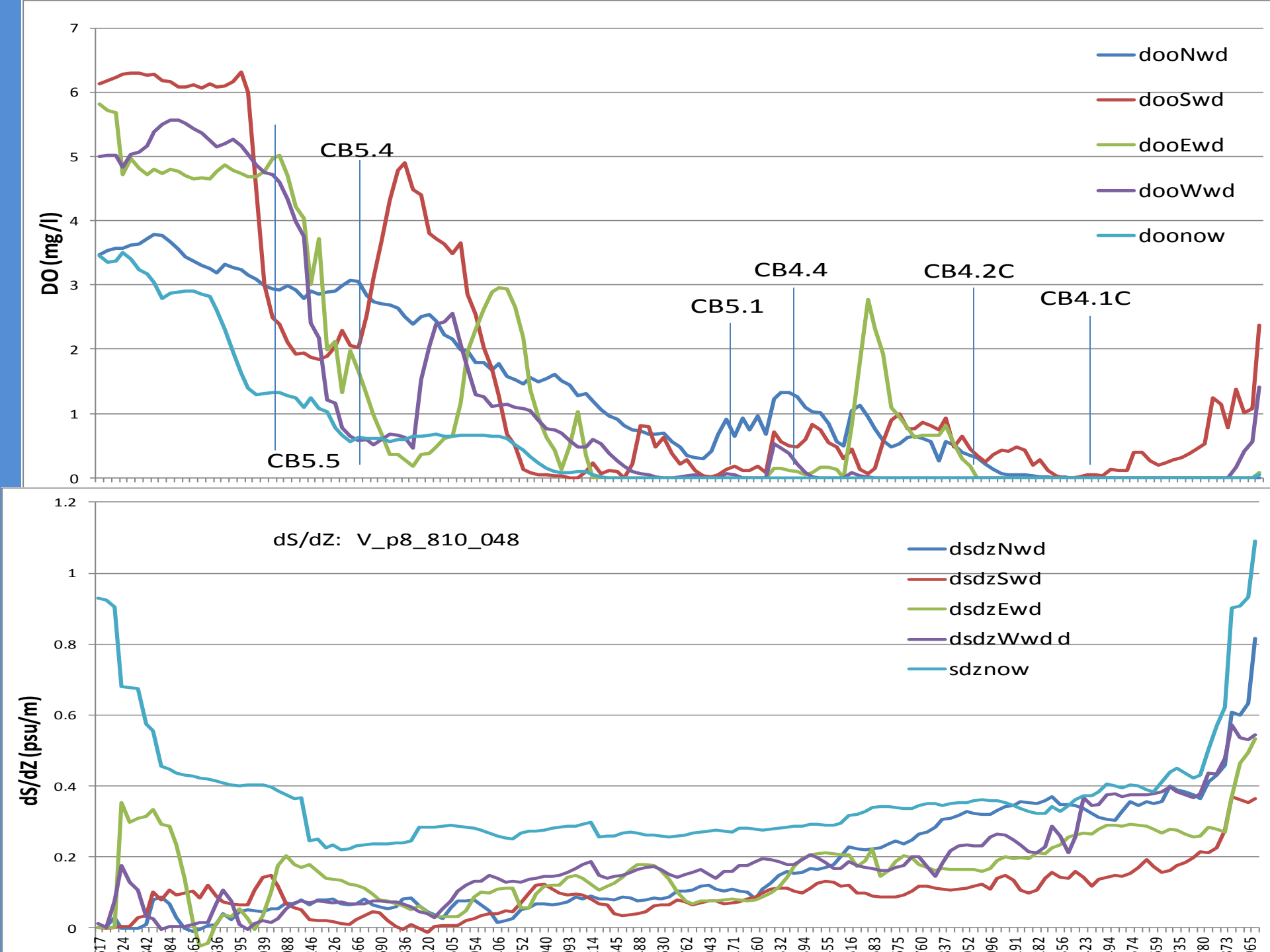



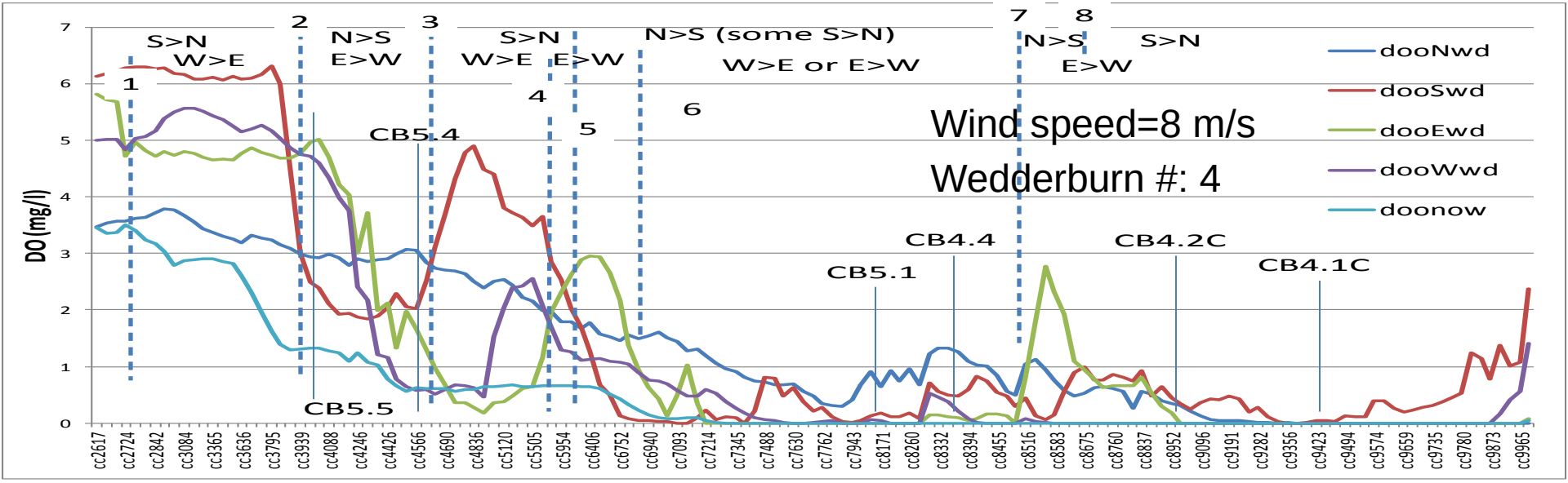

The steeper east wall than west wall of channel would favor destratif by N wind over S wind.. Such favorable is less in p3, which yields to the favorable destratif. to S wind from axial circulation.




At the west shoal E or N wind causes greater bottom DO than W or S wind; at the east shoal, W or S wind causes greater bottom DO than E or N wind.



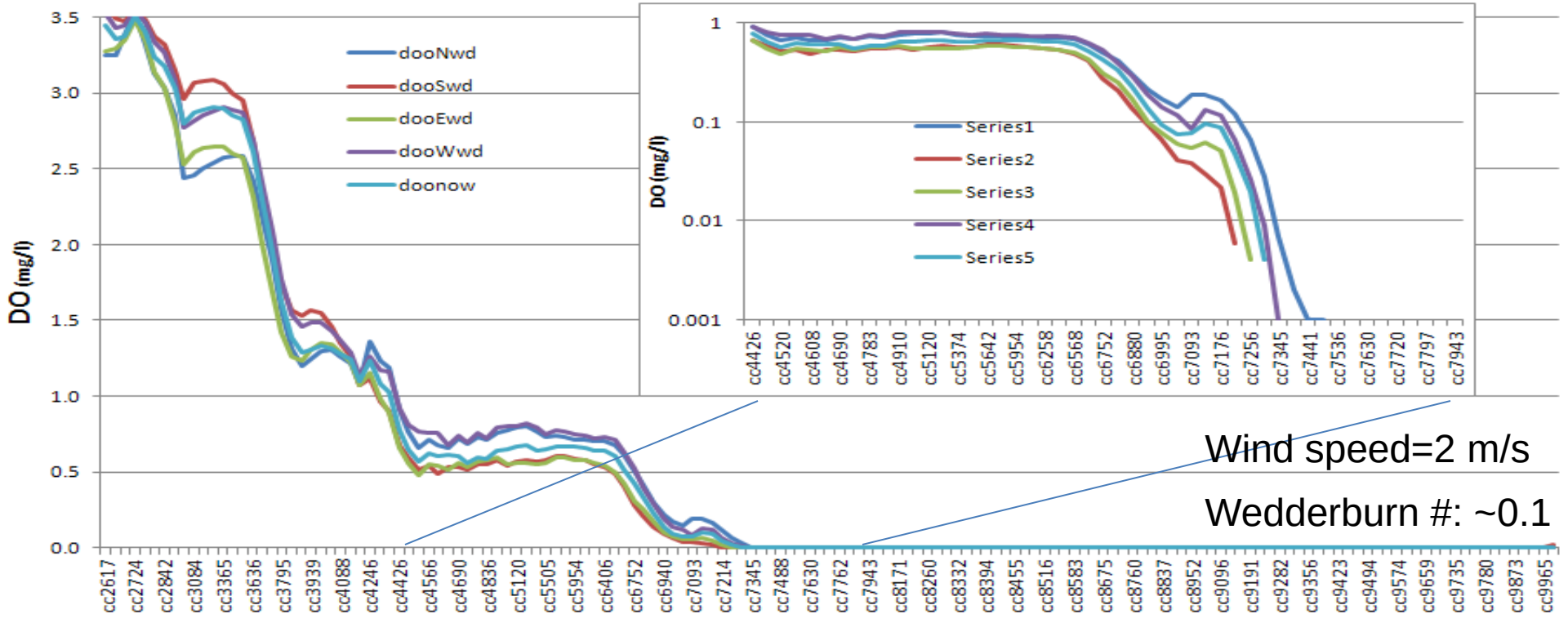

DO (mg/l)
dooNwd
dooSwd
dooEwd
dooWwd
doonow
CB5.4
CB5.5
CB5.1
CB4.4
CB4.2C
CB4.1C
dS/dZ: V_p8_810_048
dS/dZ (psu/m)
dsdzNwd
dsdzSwd
dsdzEwd
dsdzWwd.d
sdznow

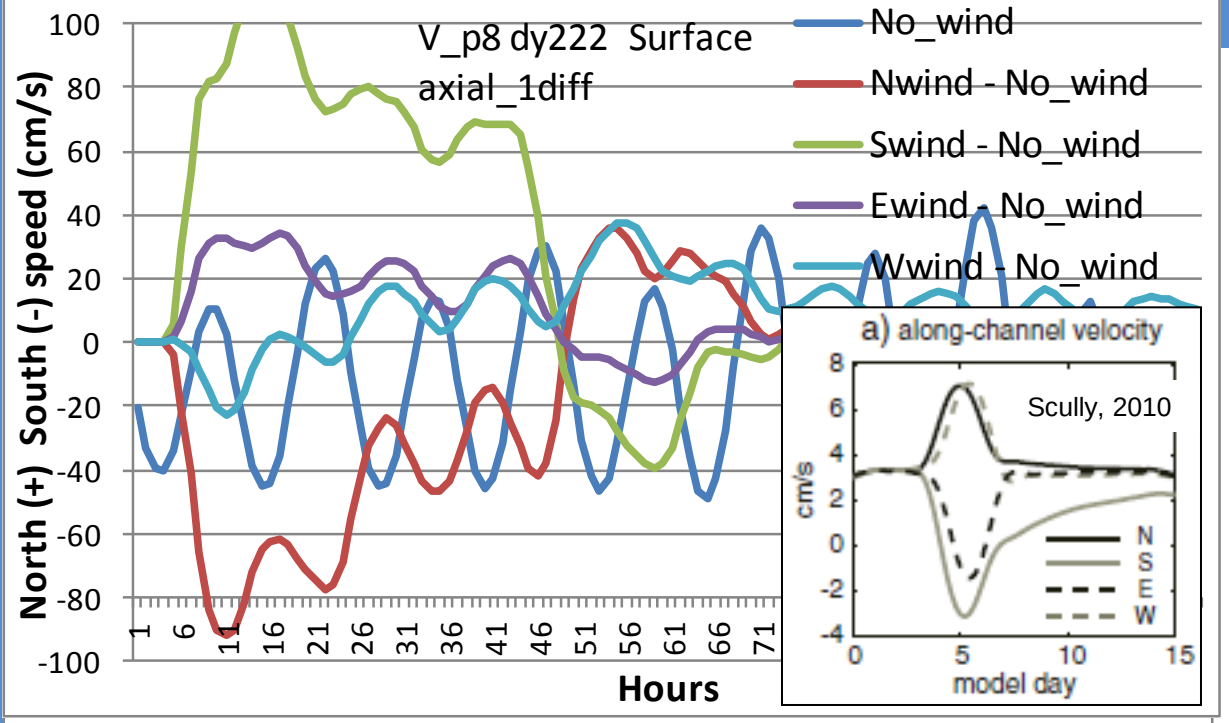


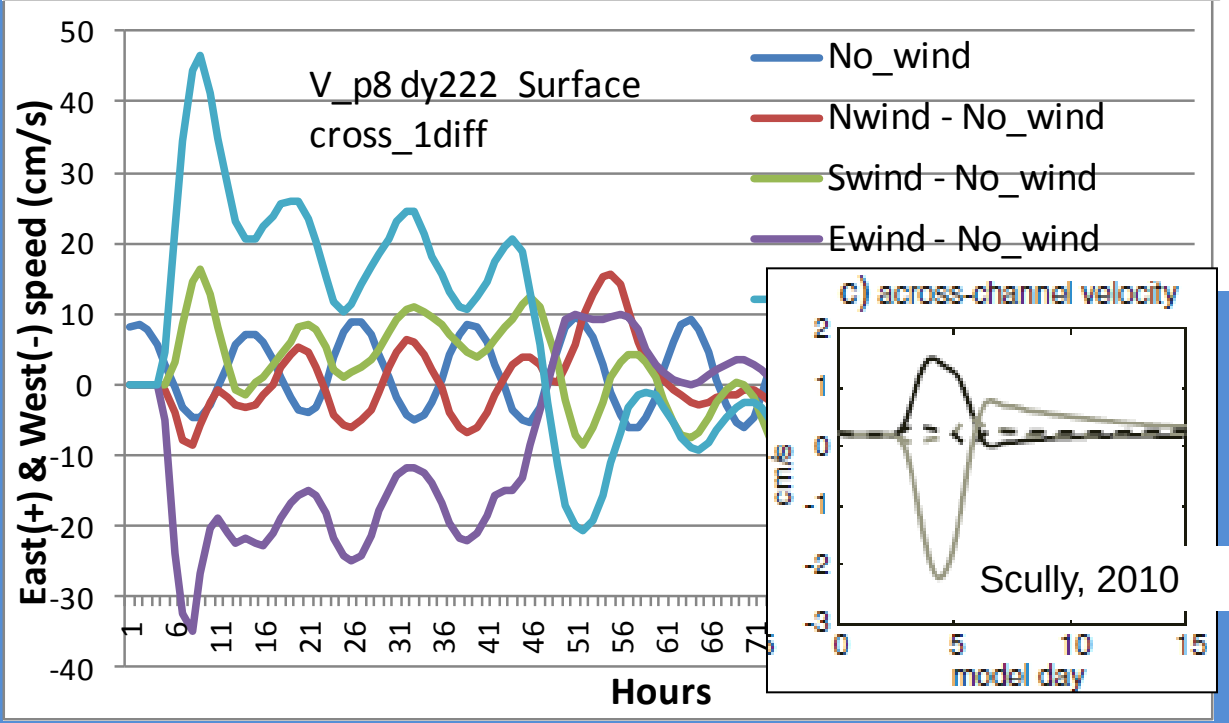

← to south, the Bay mouth

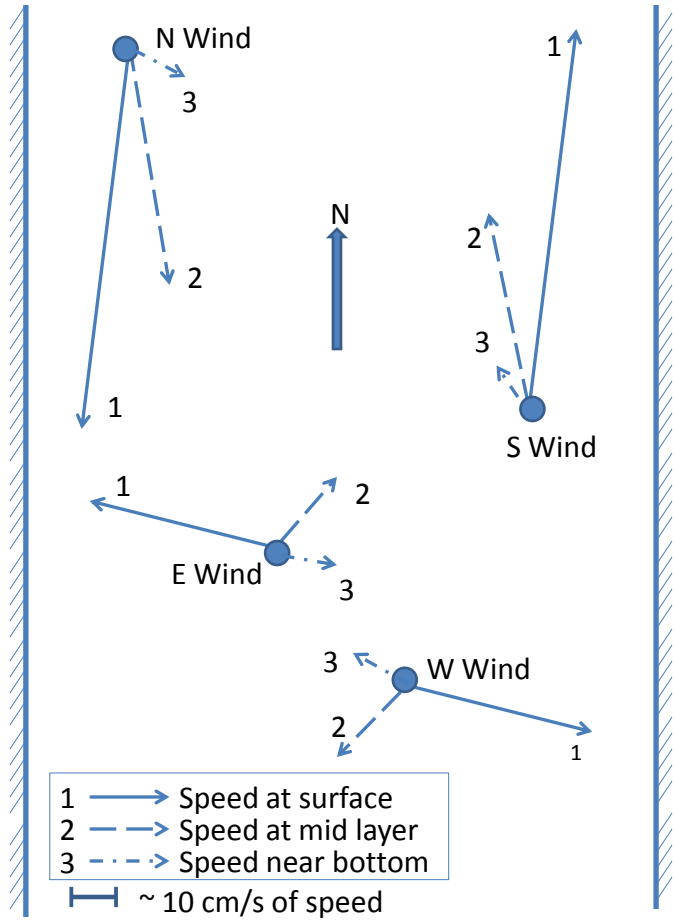
0.01-0.3 bar 3~13 m/s

to north, the Bay head →



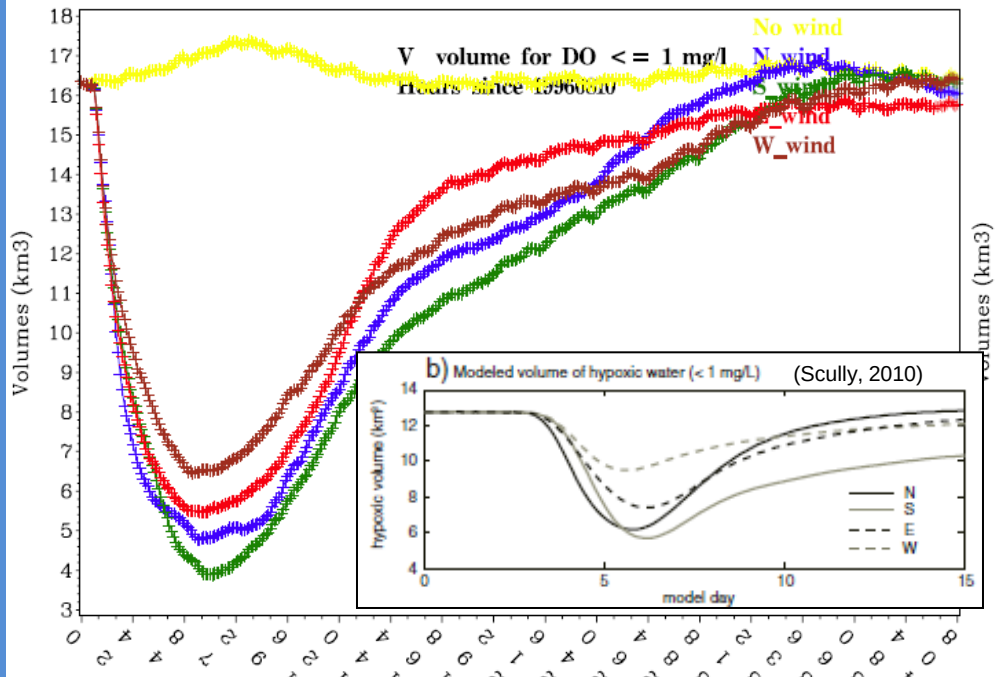


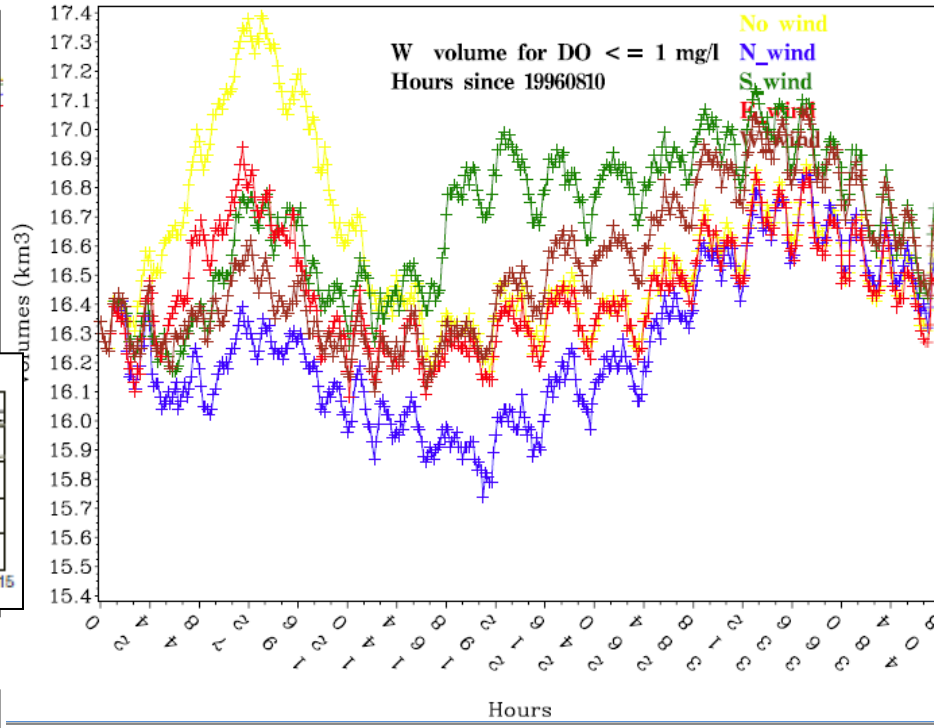



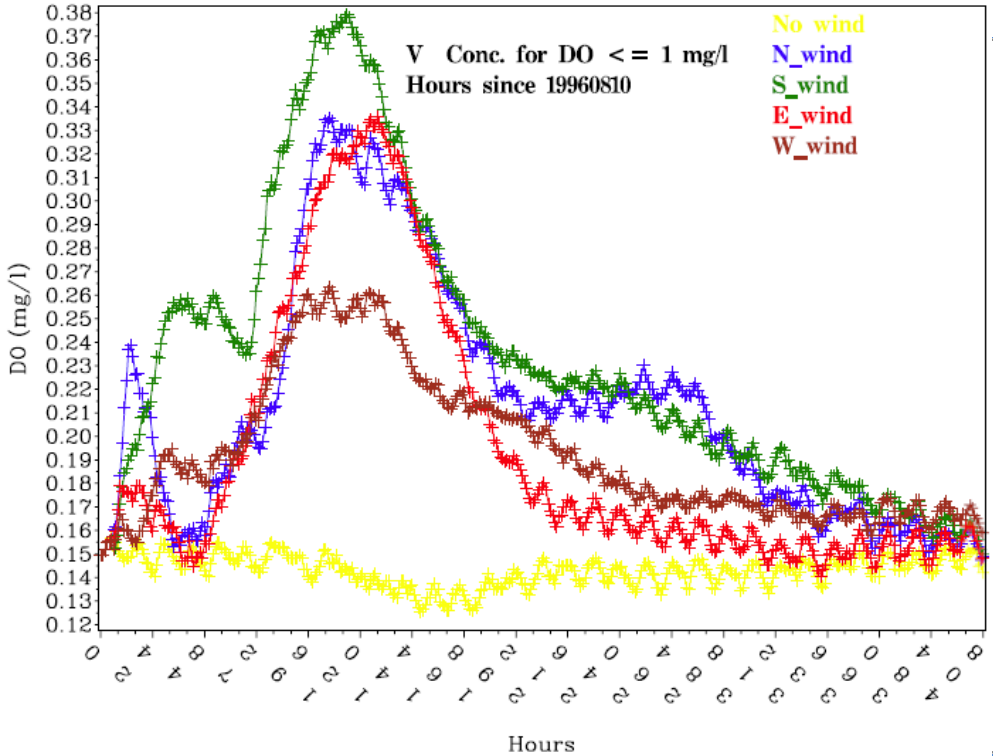



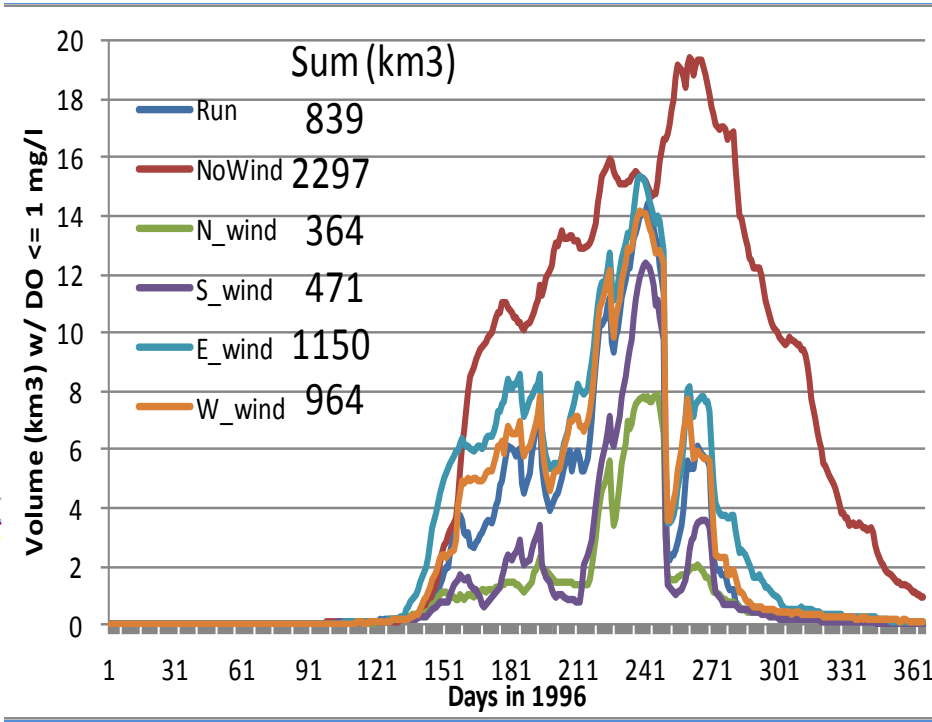

# Coriolis effect on stratified flow

Rossby number Ro = U/f/L
= 0.20/0.00009/20000 = 0.1


V volume for DO <= 1 mg/l
Hours since 19960810
No wind
N_wind
S_wind
E_wind
W_wind
Volumes (km3)
b) Modeled volume of hypoxic water (< 1 mg/L)
(Scully, 2010)
hypoxic volume (km³)
model day
N
S
E
W


W volume for DO <= 1 mg/l
Hours since 19960810
No wind
N_wind
S_wind
Hours


V Conc. for DO <= 1 mg/l
Hours since 19960810
No wind
N_wind
S_wind
E_wind
W_wind
DO (mg/l)
Hours


Sum (km3)
Run 839
NoWind 2297
N_wind 364
S_wind 471
E_wind 1150
W_wind 964
Volume (km3) w/ DO <= 1 mg/l
Days in 1996

# Conclusions

- It was found that wind may reduce stratification and summer anoxic volumes significantly. Direct wind mixing and lateral circulation are the main factors for destratification by winds.

- The shape or bathymetry of cross channel is another factor that plays an important role in causing differential influences on wind-induced circulation.

# Conclusions (cont.)

- Although there is no definite conclusion on which direction of wind causes the most in bay's destratifucation and reduces anoxic volumes, in general, at relatively strong wind, south and north winds reduce more anoxic water than east and west winds. In most locations, south wind reduces more anoxic volume than north wind, and east wind reduces more anoxic volume than west wind, though same locations display the reverse, even exhibiting the east wind to causes the greatest destratification or increase in DO.

# Conclusions (cont.)

- Although wind straining by down estuary wind may increase stratification in the Chesapeake Bay, especially in low wind speeds, our experiment still exhibits destratification at wind speed of 2 m/s.
- At low wind speeds, the favorable of cross channel bathymetry to certain wind direction on destratification usually becomes more pronounced (relative to other influencing factors), that may cause reverse in relative influences on anoxic volume or stratification by north versus south winds, or by west versus east winds at strong winds.

Thank you.