Fine-scale Features of Freshwater Lenses

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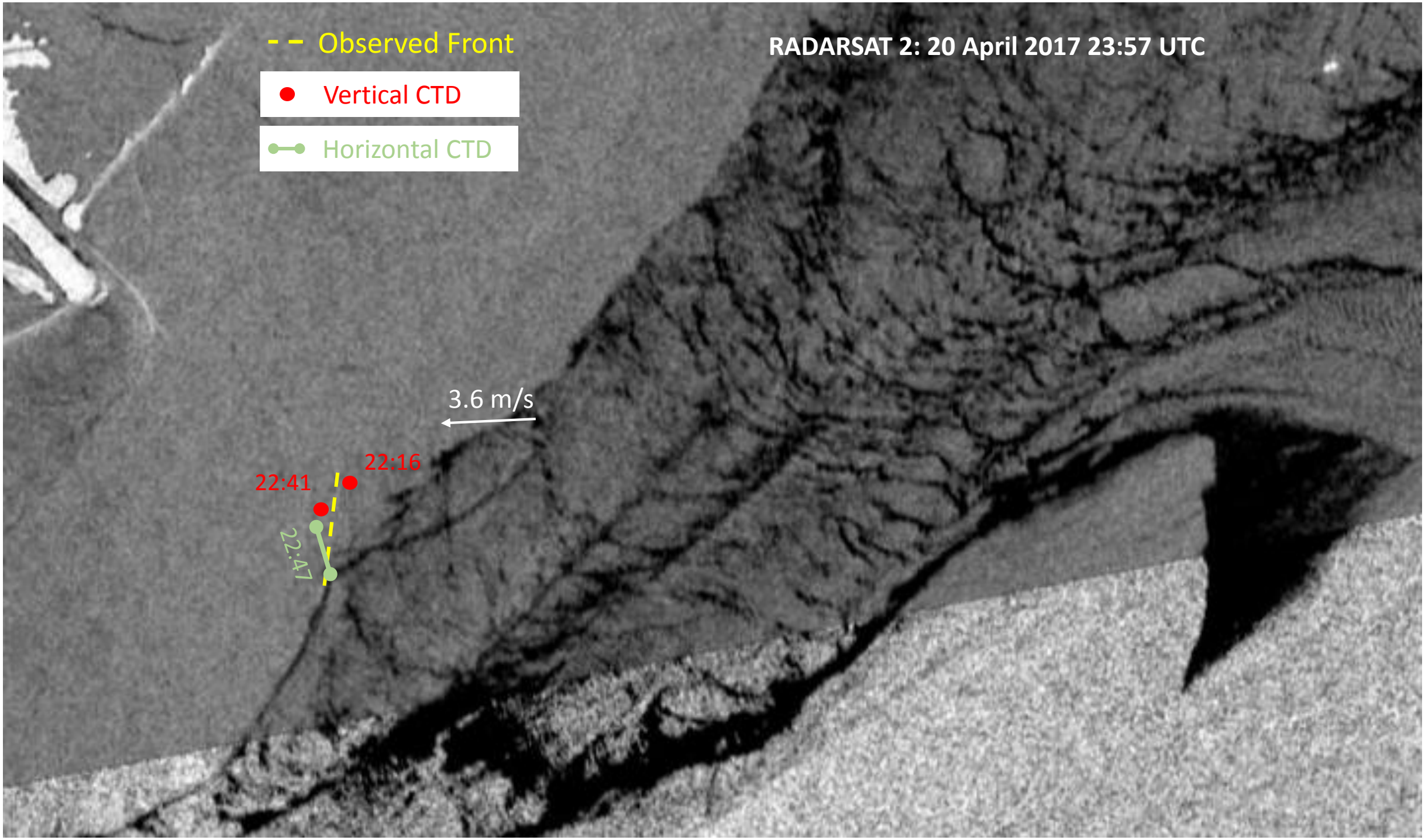
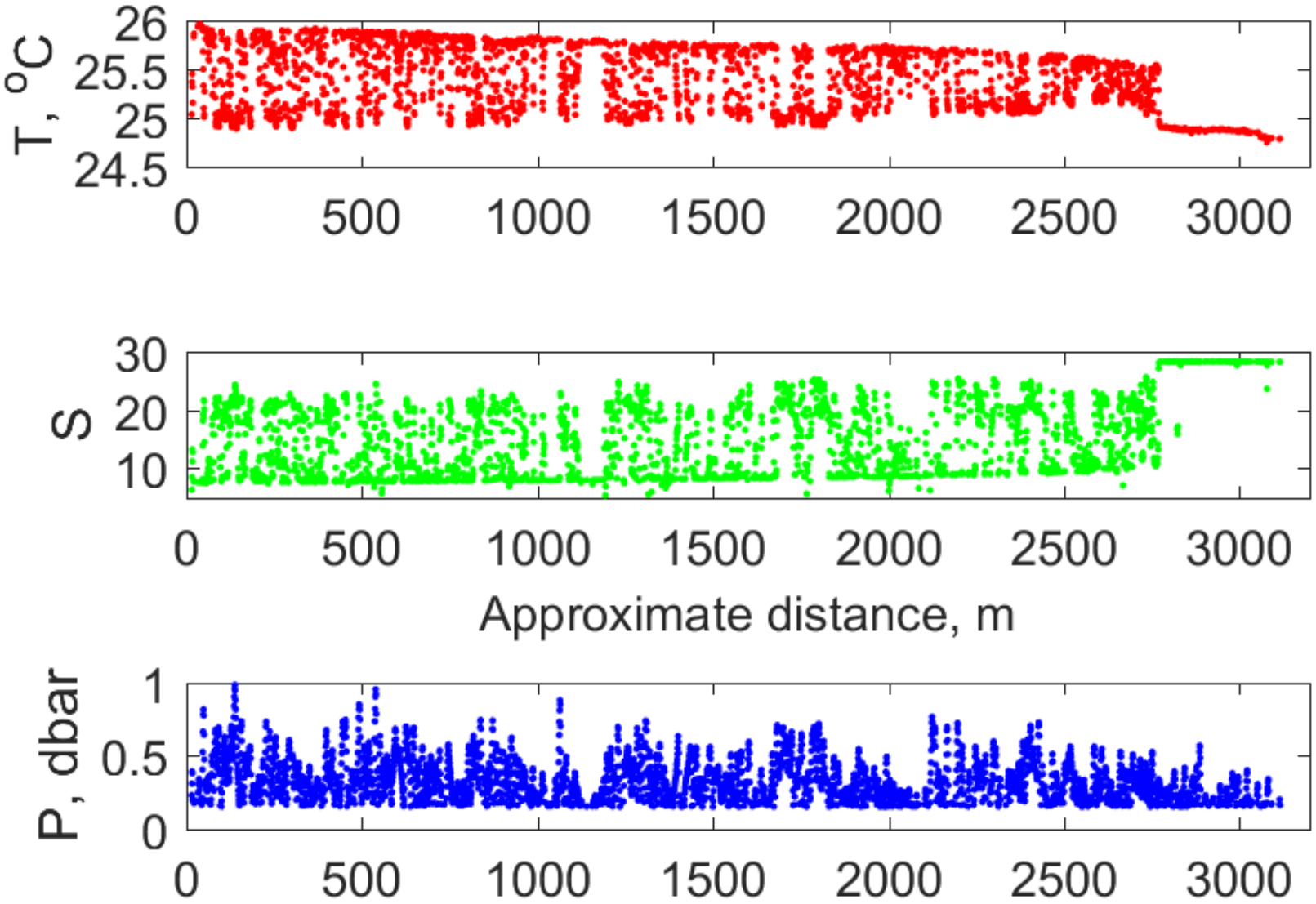

Observed Front
Vertical CTD
Horizontal CTD
RADARSAT 2: 20 April 2017 23:57 UTC
3.6 m/s
22:16
22:41
22:47

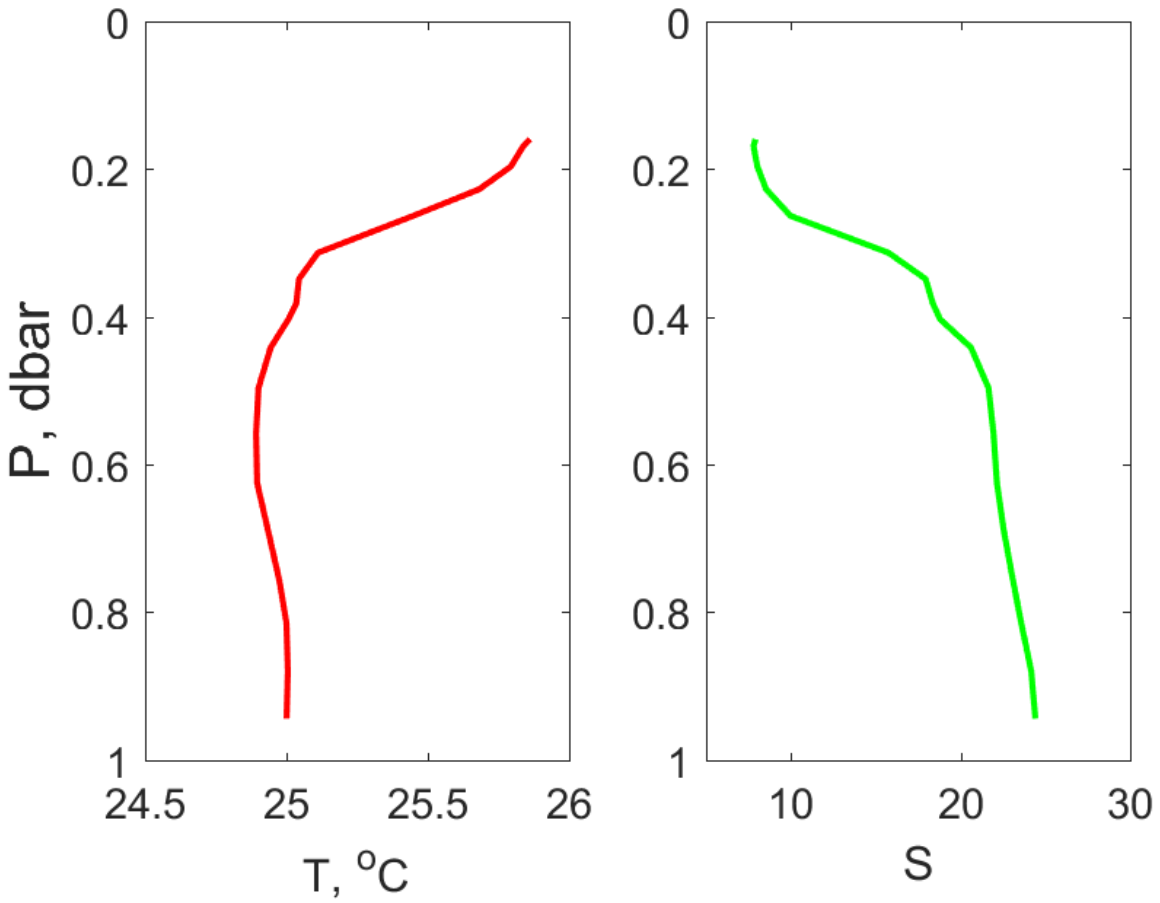
Horizontal CTD Transect

Inside lens Front Outside lens

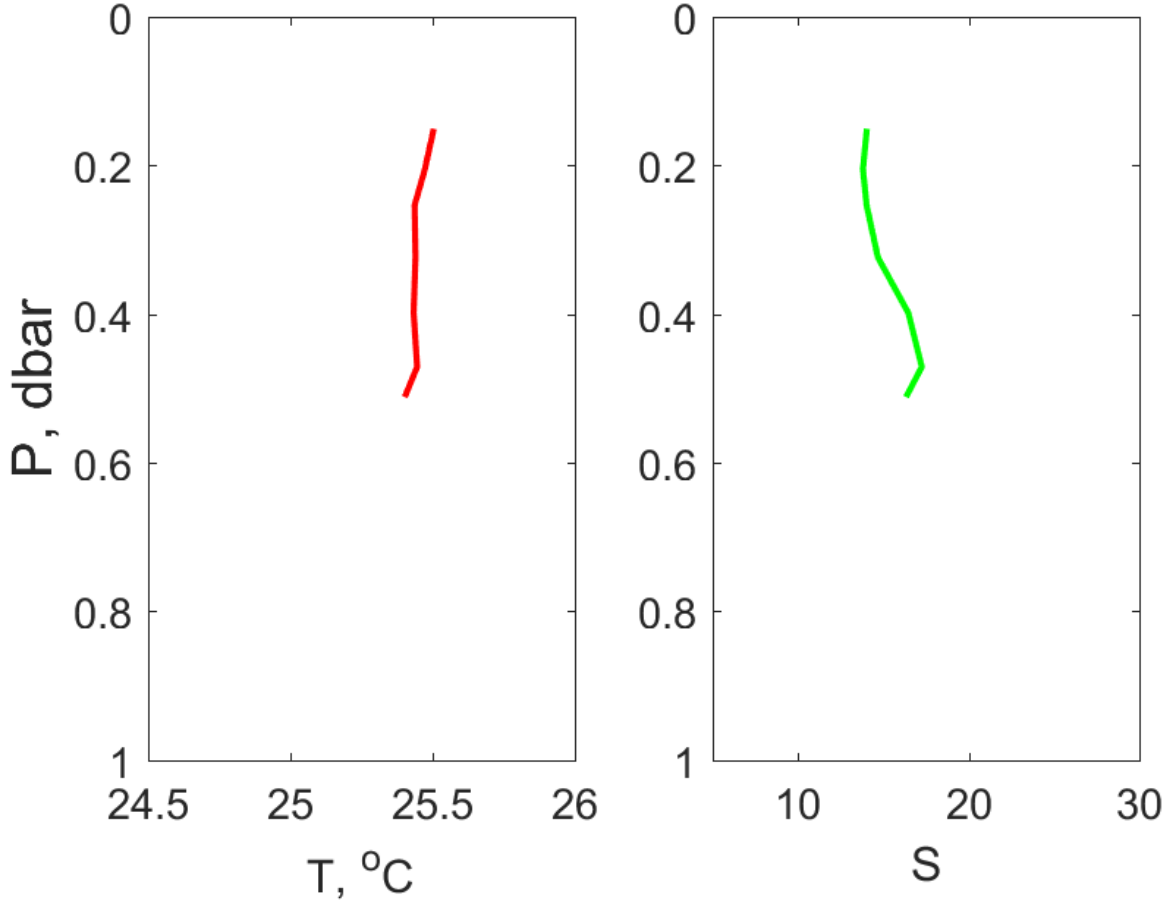


Vertical Structure of the Near-surface Layer

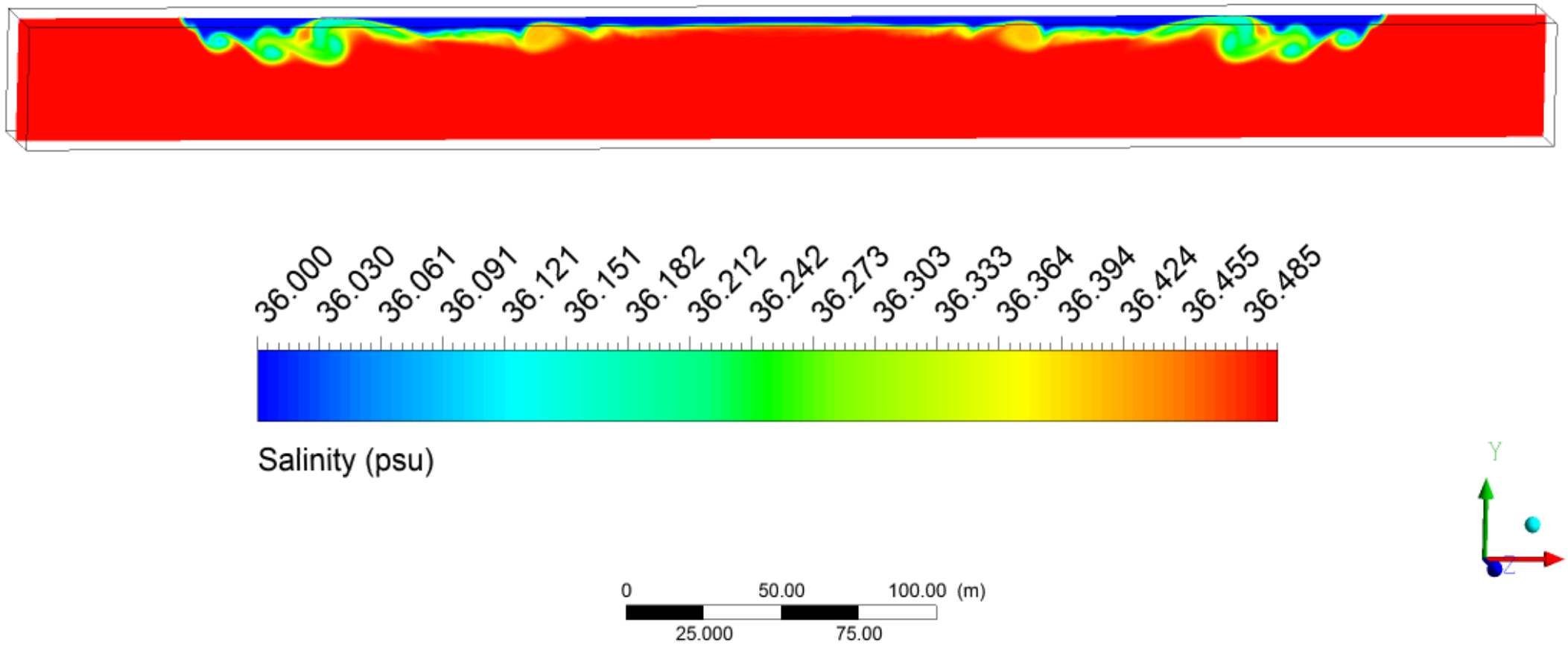
Inside lens



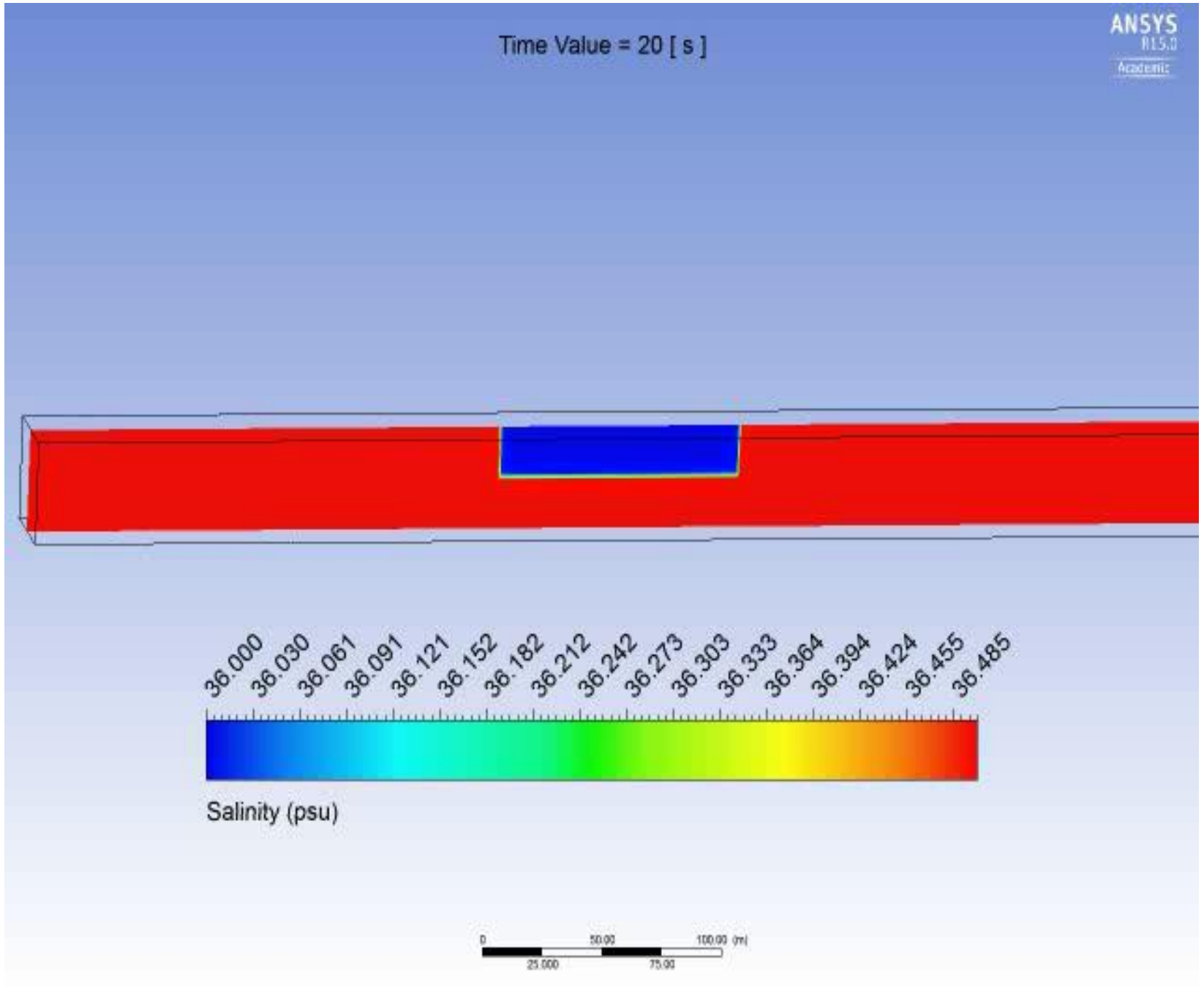
Outside lens



The freshwater lens produced by a localized source (convective rain, river run off) has tendency to propagate as a gravity current

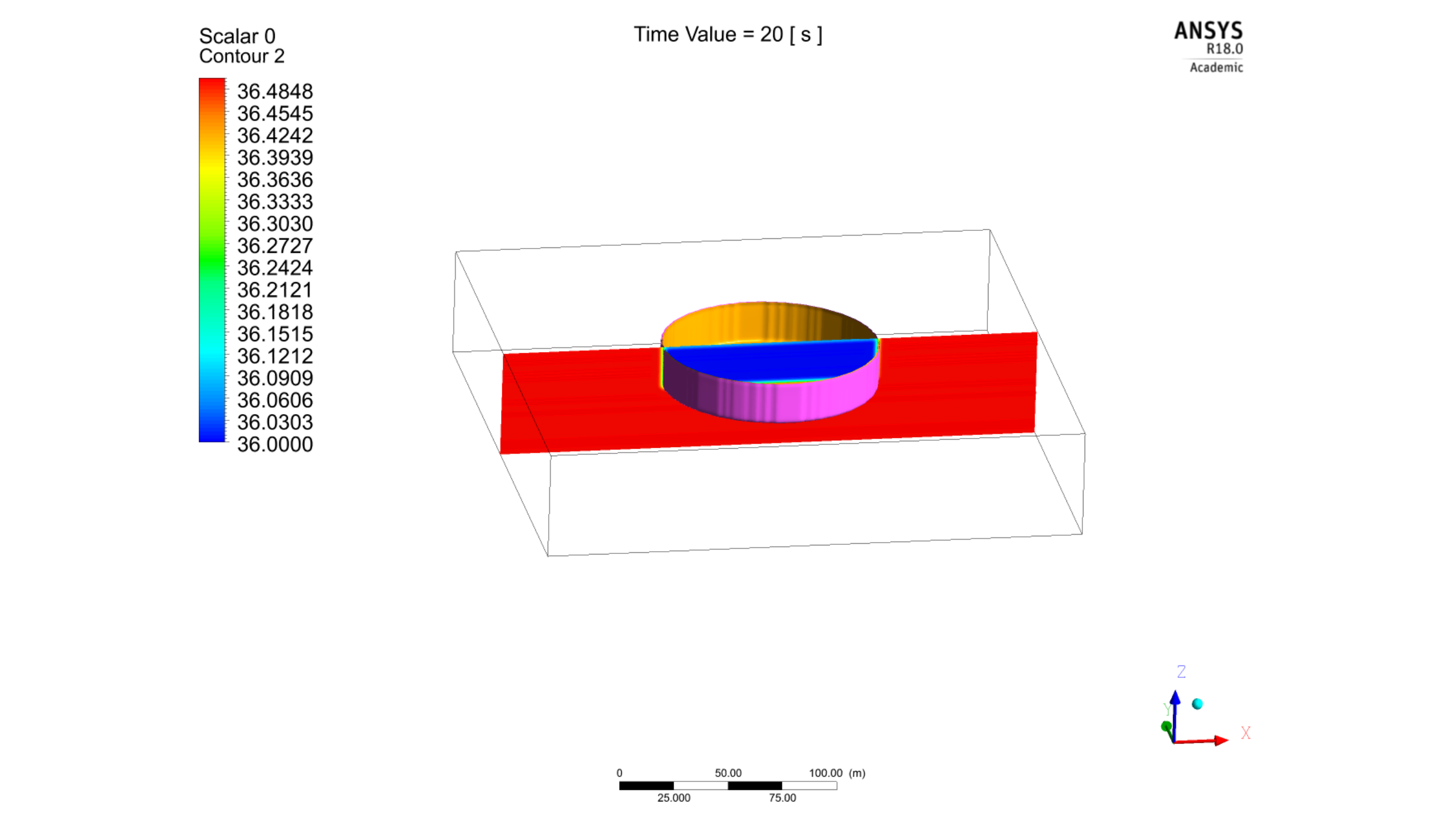


Soloviev, A.V., S. Matt, and A. Fujimura, 2015: Three-Dimensional Dynamics of Freshwater Lenses in the Ocean's Near-Surface Layer. *Oceanography* 28(1):142–149, 2015.



Lens asymmetry due to wind action

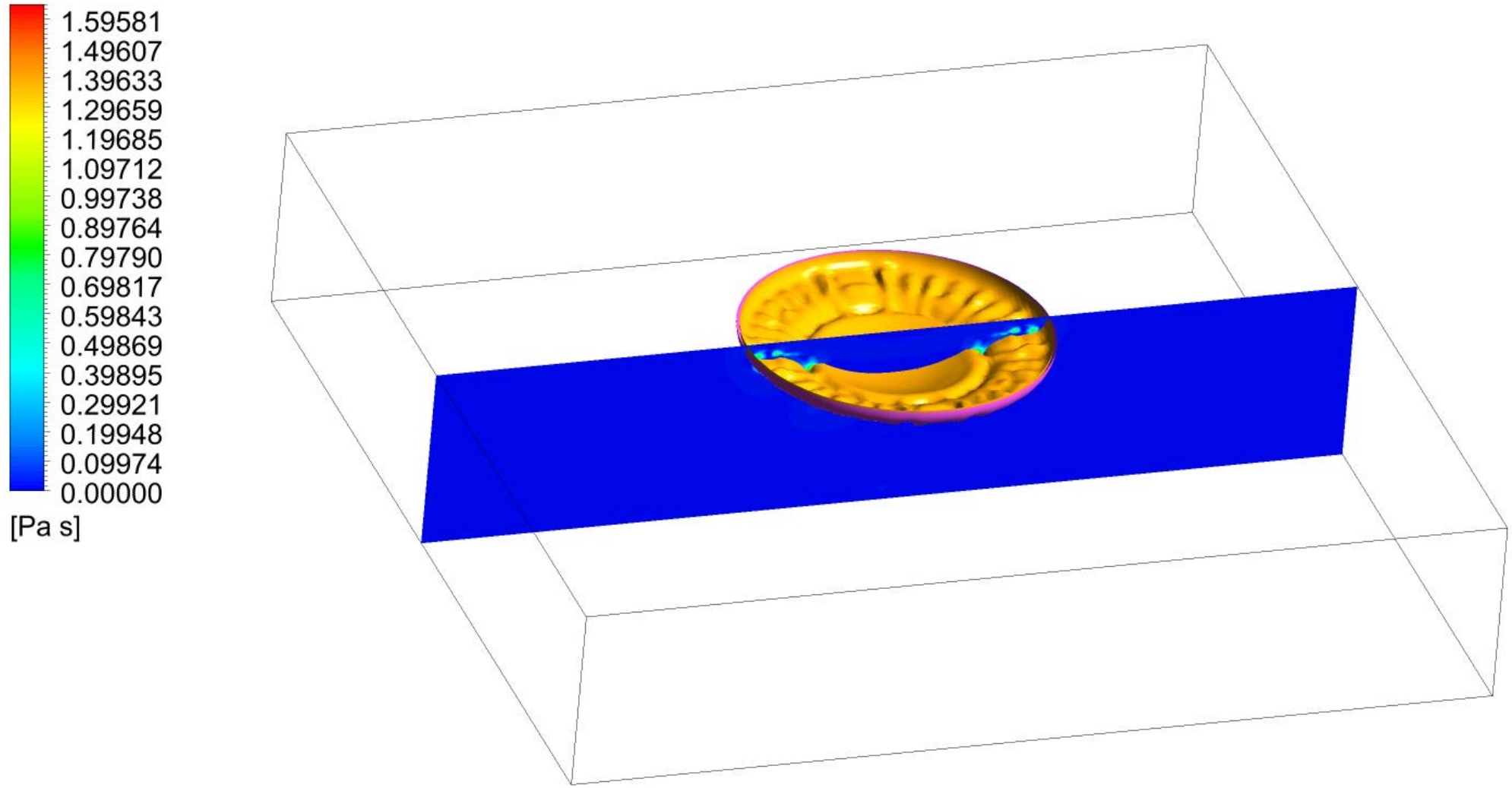
U_{10} = 8 m/s


Scalar 0
Contour 2
36.4848
36.4545
36.4242
36.3939
36.3636
36.3333
36.3030
36.2727
36.2424
36.2121
36.1818
36.1515
36.1212
36.0909
36.0606
36.0303
36.0000
Time Value = 20 [s]
ANSYS
R18.0
Academic
Z
Y
X
0
50.00
100.00 (m)
25.000
75.00

Eddy Viscosity
Contour 2

Time Value = 260 [s]

ANSYS
R18.0
Academic

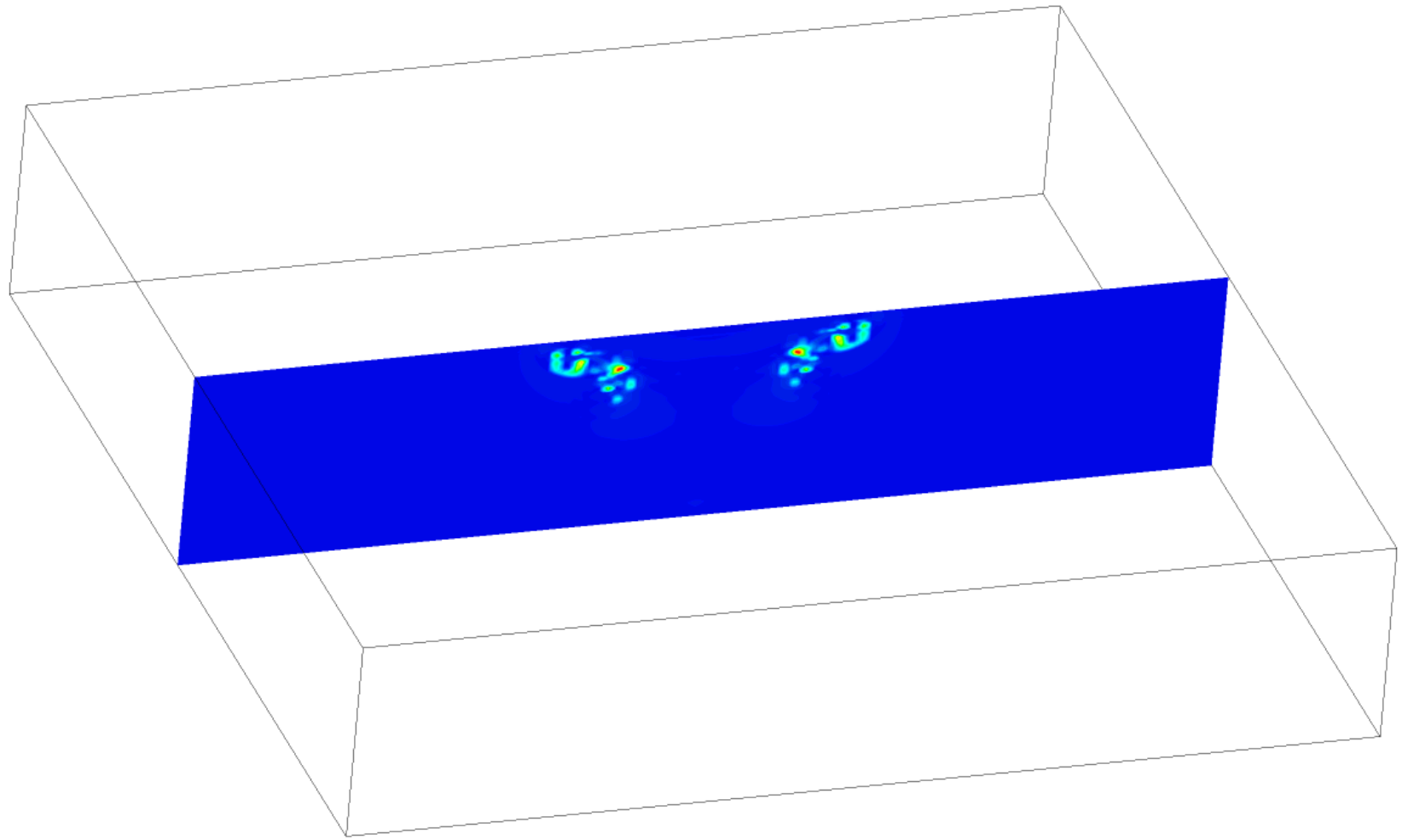


Eddy Viscosity
Contour 2

Time Value = 260 [s]

ANSYS
R18.0
Academic

1.59581
1.49607
1.39633
1.29659
1.19685
1.09712
0.99738
0.89764
0.79790
0.69817
0.59843
0.49869
0.39895
0.29921
0.19948
0.09974
0.00000
[Pa s]



Z
Y
X

0 50.00 100.00 (m)
25.000 75.00

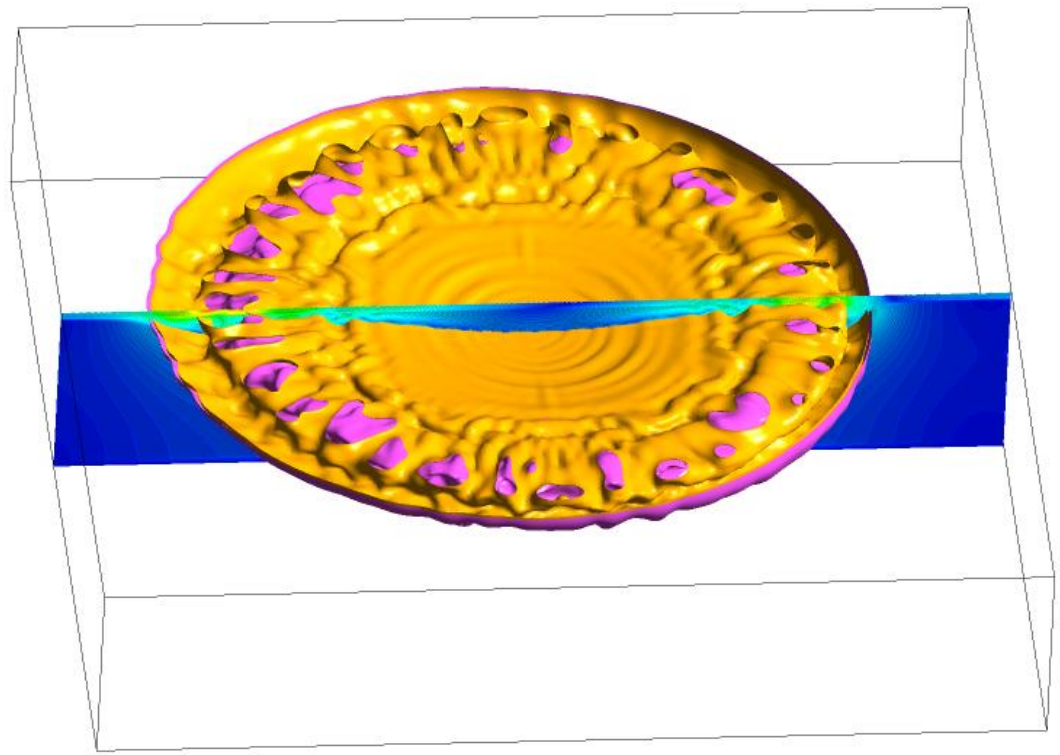
Velocity
Contour 2

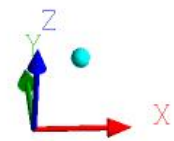
0.2365
0.2217
0.2069
0.1921
0.1773
0.1626
0.1478
0.1330
0.1182
0.1035
0.0887
0.0739
0.0591
0.0443
0.0296
0.0148
0.0000

[m s^-1]

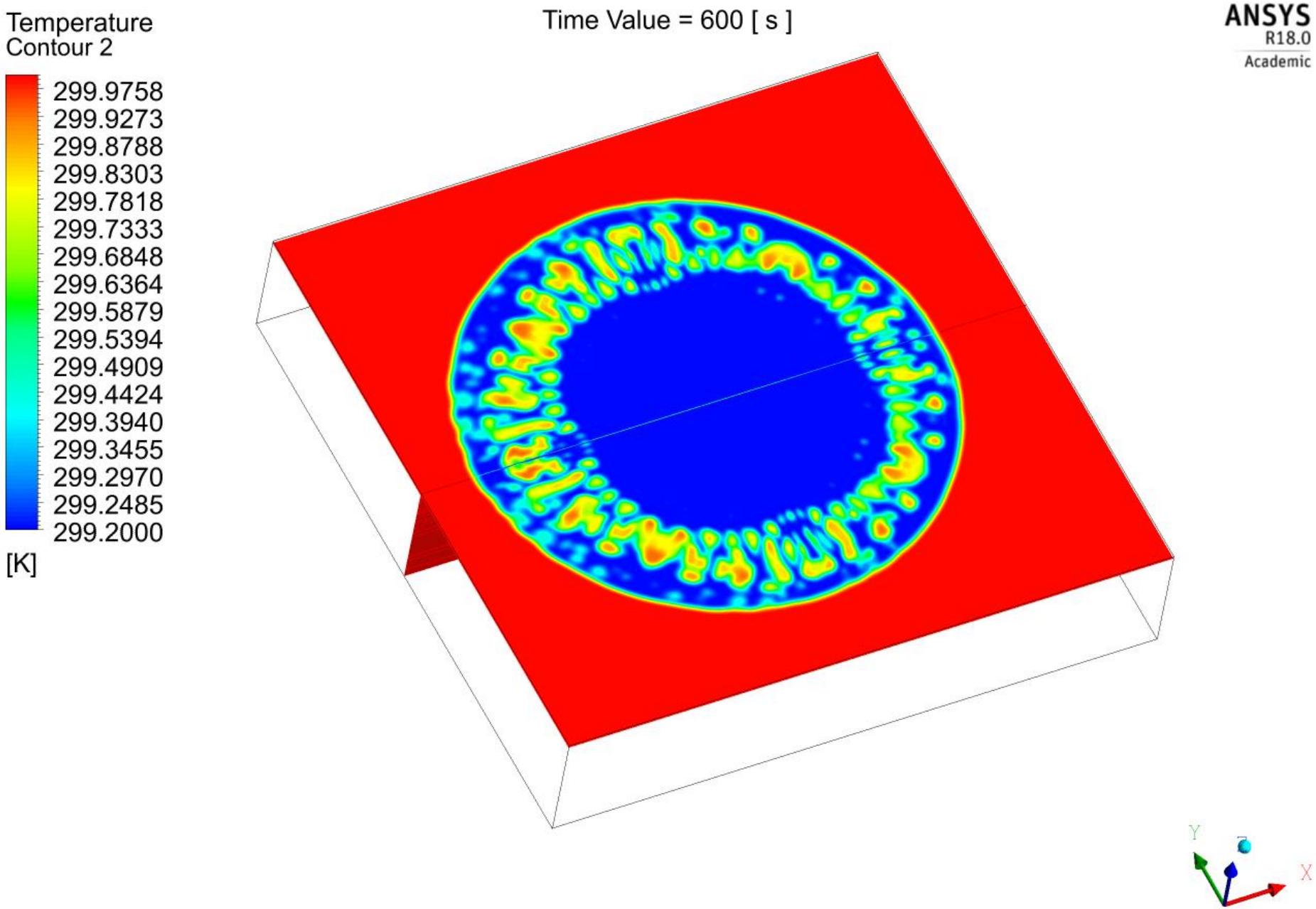
Time Value = 600 [s]

ANSYS
R18.0
Academic





0 50.00 100.00 (m)
25.000 75.00


Temperature
Contour 2
299.9758
299.9273
299.8788
299.8303
299.7818
299.7333
299.6848
299.6364
299.5879
299.5394
299.4909
299.4424
299.3940
299.3455
299.2970
299.2485
299.2000
[K]
Time Value = 600 [s]
ANSYS
R18.0
Academic
Y
Z
X
0
50.00
100.00 (m)

Modeling Freshwater Lens - Wind Interaction

Numerical domain: $X \times Y \times Z = 500\,\mathrm{m} \times 500\,\mathrm{m} \times 80\,\mathrm{m}$

Mesh size: 10×10^6

$$Ro = \frac{U}{fL} \approx \frac{0.1\ \mathrm{m\ s^{-1}}}{5 \cdot 10^{-5}\ \mathrm{s^{-1}} \cdot 100\ \mathrm{m}} = 20 \gg 1$$

Large Rossby number – direct effect of Coriolis negligible

Need to increase horizontal sizes by a factor of 100, which would require result the mesh size 10×10^9

Coriolis Effect

$$\rho\left(\frac{Du}{Dt} - fv + f_y w\right) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z}$$

$$\rho\left(\frac{Dv}{Dt} + fu\right) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z}$$

$$\rho\left(\frac{Dw}{Dt} - f_y u\right) = -\rho g - \frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}$$

Coriolis Effect (no wind stress)

$$\rho\left(\frac{Du}{Dt} - fv + f_y w\right) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z}$$

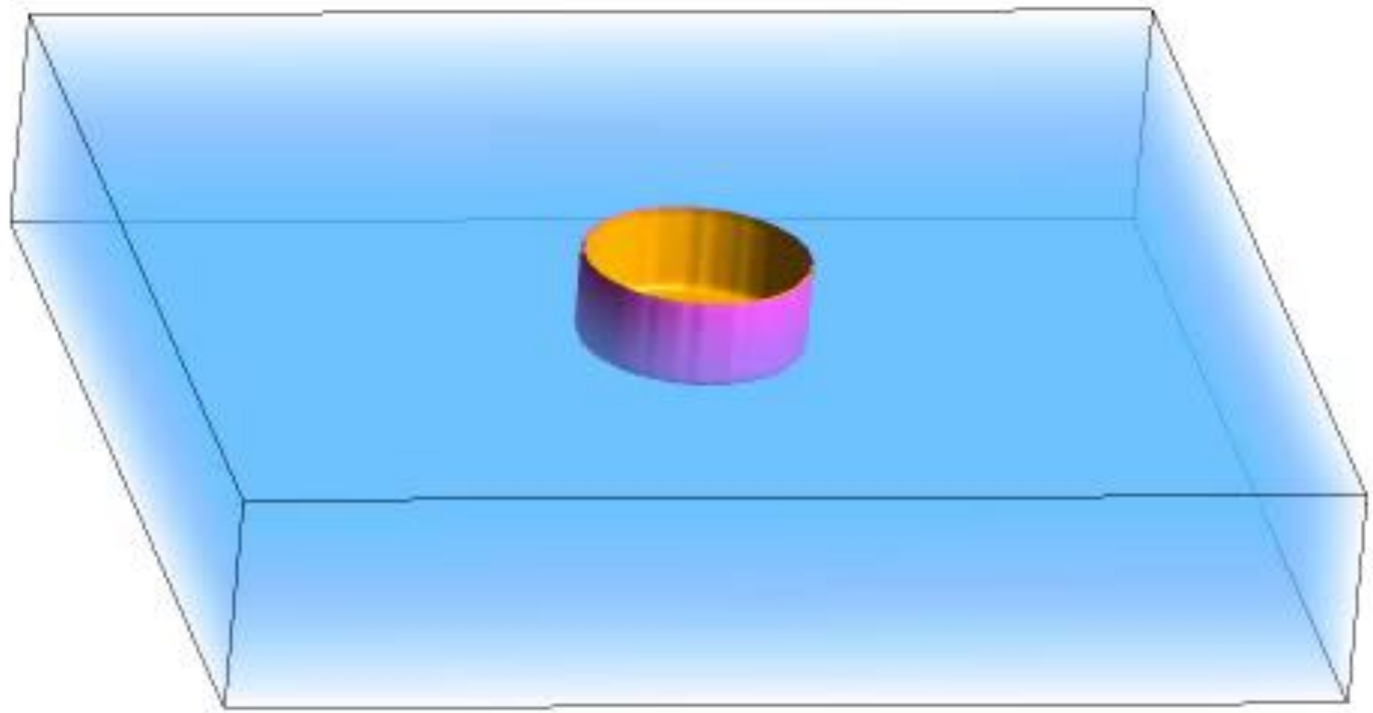
$$\rho\left(\frac{Dv}{Dt} + fu\right) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z}$$

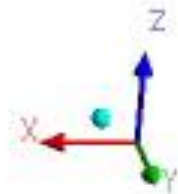
$$\rho\left(\frac{Dw}{Dt} - f_y u\right) = -\rho g - \frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}$$

… and increased *f* by a factor of 100: $Ro = 0.2 \not\ll 1$

Time Value = 20 [s]

ANSYS
R18.0
Academic





Conclusions

- Freshwater lenses appear to act as a barrier to the propagation of the oil slick.
- Freshwater lenses are localized in thin near-surface layers, sometimes less than 1 m deep, which may explain the transient nature of these lenses.
- We continue numerical simulations of freshwater lenses using computational fluid dynamics (CFD) tools in the framework of the CARTHE/GoMRI project.
- The available field data serve as a guide.
- We would be happy to apply this modeling suit for simulation of the SPURS data on freshwater lenses.