VARIABLE ATMOSPHERIC FLUX NEUMANN BOUNDARY CONDITIONS FOR 2D DYNAMIC OCEAN FLOWS

SPRING 2.29 PROJECT

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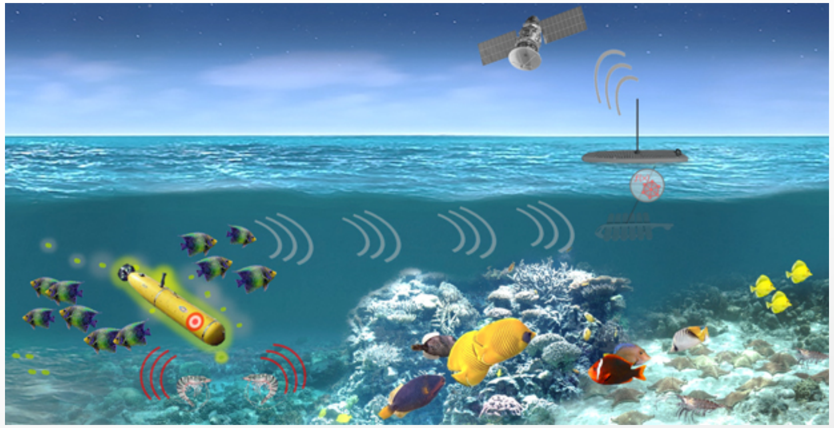
INSPIRATION – ACOUSTIC ENVIRONMENT PREDICTION

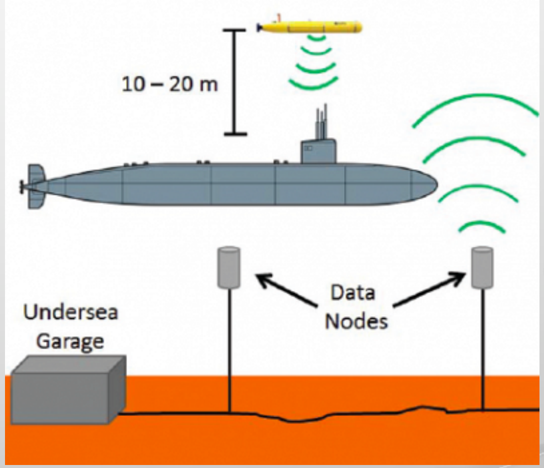


- DENSITY (SOUND SPEED) PROFILE IS ESSENTIAL FOR NUMEROUS APPLICATIONS:

  -ACOUSTIC COMMUNICATION, SENSING, AND NAVIGATION

- DYNAMIC NATURE OF THE OCEAN ENVIRONMENT WILL RESULT IN LARGE CHANGES IN THE DENSITY PROFILE, ESPECIALLY IN THE UPPER PORTIONS OF THE WATER COLUMN KNOWN AS THE THERMOCLINE.

- SAMPLING OR MEASURING PARAMETERS AFFECTING DENSITY (TEMPERATURE, SALINITY, PRESSURE) IS NOT ALWAYS FEASIBLE, MAKING IT NECESSARY TO ACCURATELY PREDICT HOW THESE PARAMETERS MAY CHANGE OVER A GIVEN TIME PERIOD BETWEEN SAMPLING.

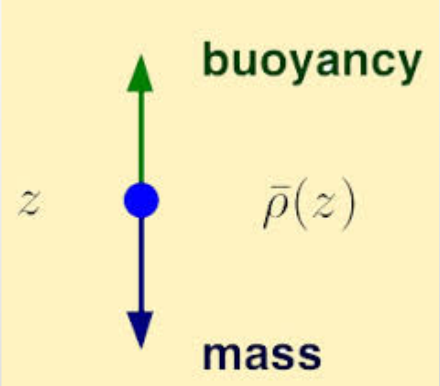


APPROACH – BOUSSINESQ APPROXIMATION

- BOUSSINESQ APPROXIMATION: ASSUMING THAT VARIATION IN DENSITY IS ONLY FOR THE GRAVITY FORCING, BOUSSINESQ EQUATIONS ARE USED TO MODEL THE INTERACTION BETWEEN VELOCITY AND DENSITY FIELDS.

$$\rho_0\left(\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u}\cdot\nabla\mathbf{u}\right) = -\nabla p + \mu\nabla^2\mathbf{u} + (\rho_0 + \Delta\rho)\mathbf{g}$$

$$-\nabla p + (\rho_0 + \Delta\rho)\mathbf{g} \qquad -\nabla P + \Delta\rho\mathbf{g}$$



$$\frac{1}{\rho}\frac{D\rho}{Dt} + \nabla\cdot\mathbf{u} = 0$$

*Assumes the change in density is only significant in front of the gravity term. Variation in density for the ocean is ~0.005 kg/m^3

APPROACH – EQUATION OF STATE FOR DENSITY

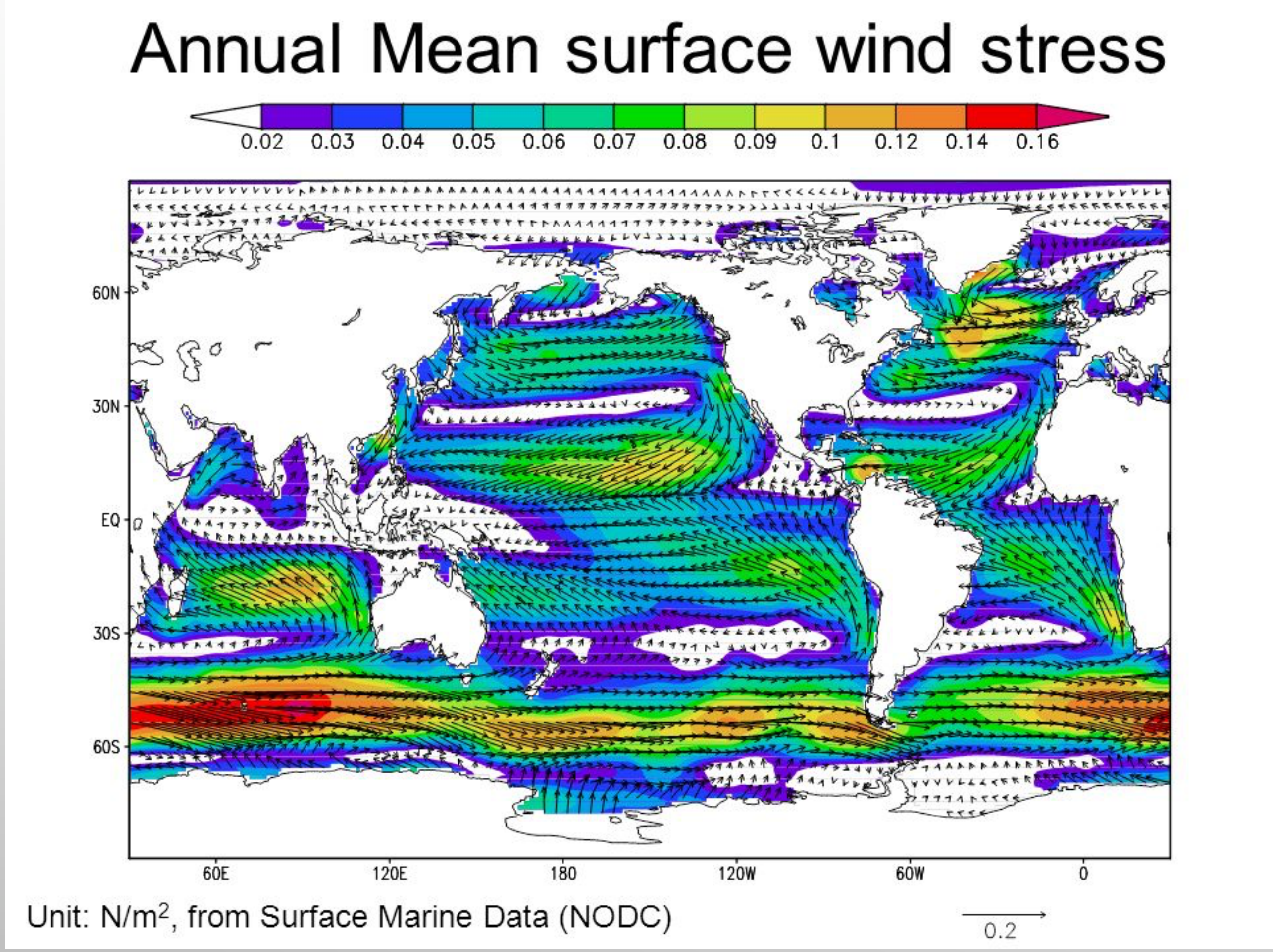
- USING THE EQUATION OF STATE, I ALSO MODEL CHANGES IN THE VELOCITY FIELD DUE TO WIND FORCING. (REFERENCE DENSITY 1025 KG/M^3)

$$\sigma = \sigma_o + \rho_{ref}\left[\beta_S(S - S_o) - \alpha_T(T - T_o)\right]$$

- CAN IMPLEMENT A SPACE AND TIME DEPENDENT NEUMANN BOUNDARY CONDITION ON DENSITY TO THE TOP SURFACE OF THE OCEAN.

- FOR A TEST CASE I APPLY THE UPPER BOUNDARY CONDITION FOR FLOW OVER SEAMOUNT.

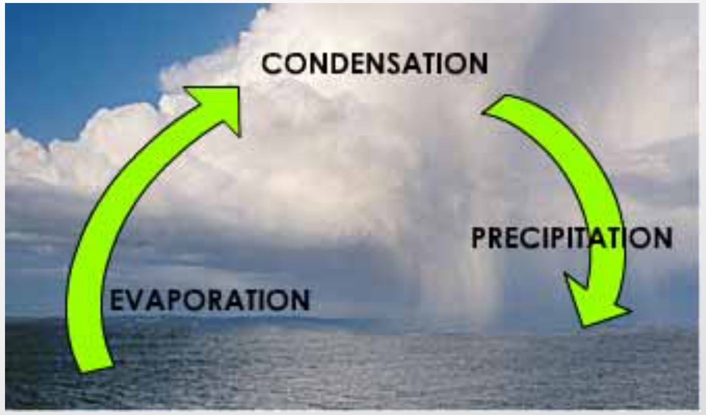
TIME DEPENDENT NEUMANN BOUNDARY CONDITION ON THE TOP SURFACE OF THE OCEAN.



- Wind stress (horizontal velocity at the top boundary)
- the wind stress:
  - $du/dz = c_d * \rho_{air} * |u_{10}| * u_{10}$
  - ρ_{air} is the density of air, 1.3 kg/m^3
  - c_d is the drag coefficient, 0.0014 (non-dimensional)
- change in density: $d\rho'/dz = \beta * dS/dz + \alpha * dT/dz$

CHANGE IN DENSITY – EVAPORATION/PRECIPITATION

- THE SURFACE FLUX OF WATER OUT OF THE OCEAN, FH2O (CM/DAY), IS GIVEN BY THE DIFFERENCE OF EVAPORATION AND PRECIPITATION
  - $F_{H2O} = \rho_{H2O}E - P_{RAIN}$
    - ρ_{H2O} IS THE DENSITY OF WATER, 1000 KG/M3
    - P_{RAIN} IS THE PRECIPITATION RATE (CM/DAY)
    - E IS EVAPORATION RATE (CM/DAY)



- TO NOT HAVE THE LEVEL OF OCEAN RISE OR FALL, DIVIDE BY A "SALT DIFFUSION COEFFICIENT" K: $dS/dz = (\rho_{H2O}E - P_{RAIN})/\text{-}K$

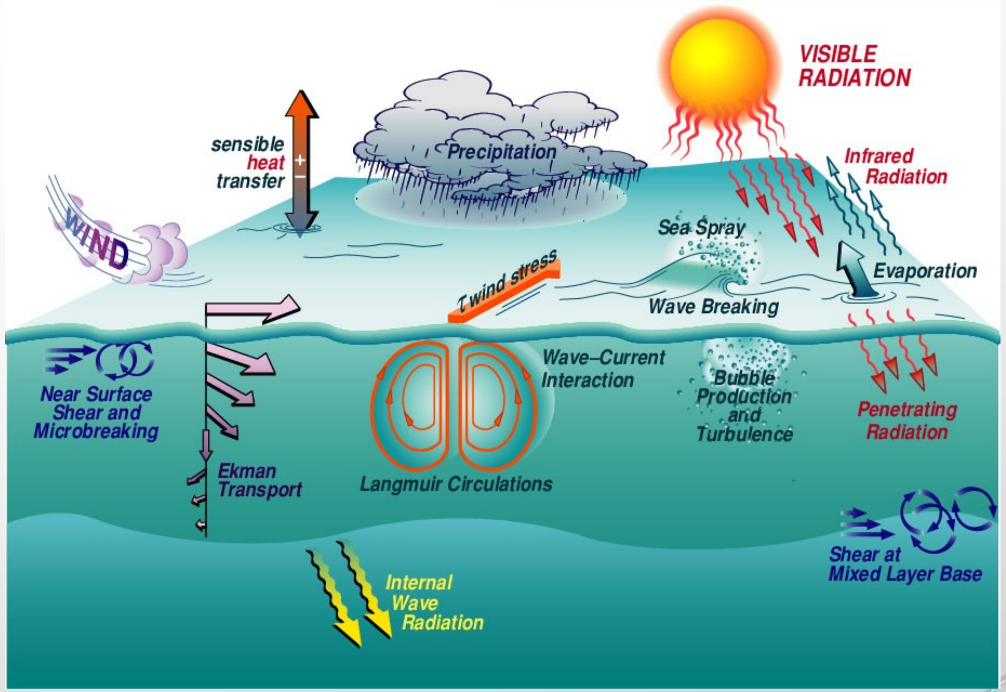
CHANGE IN DENSITY – HEAT TRANSFER

$$Q_{NET} = Q_I - Q_B - Q_L - Q_S$$

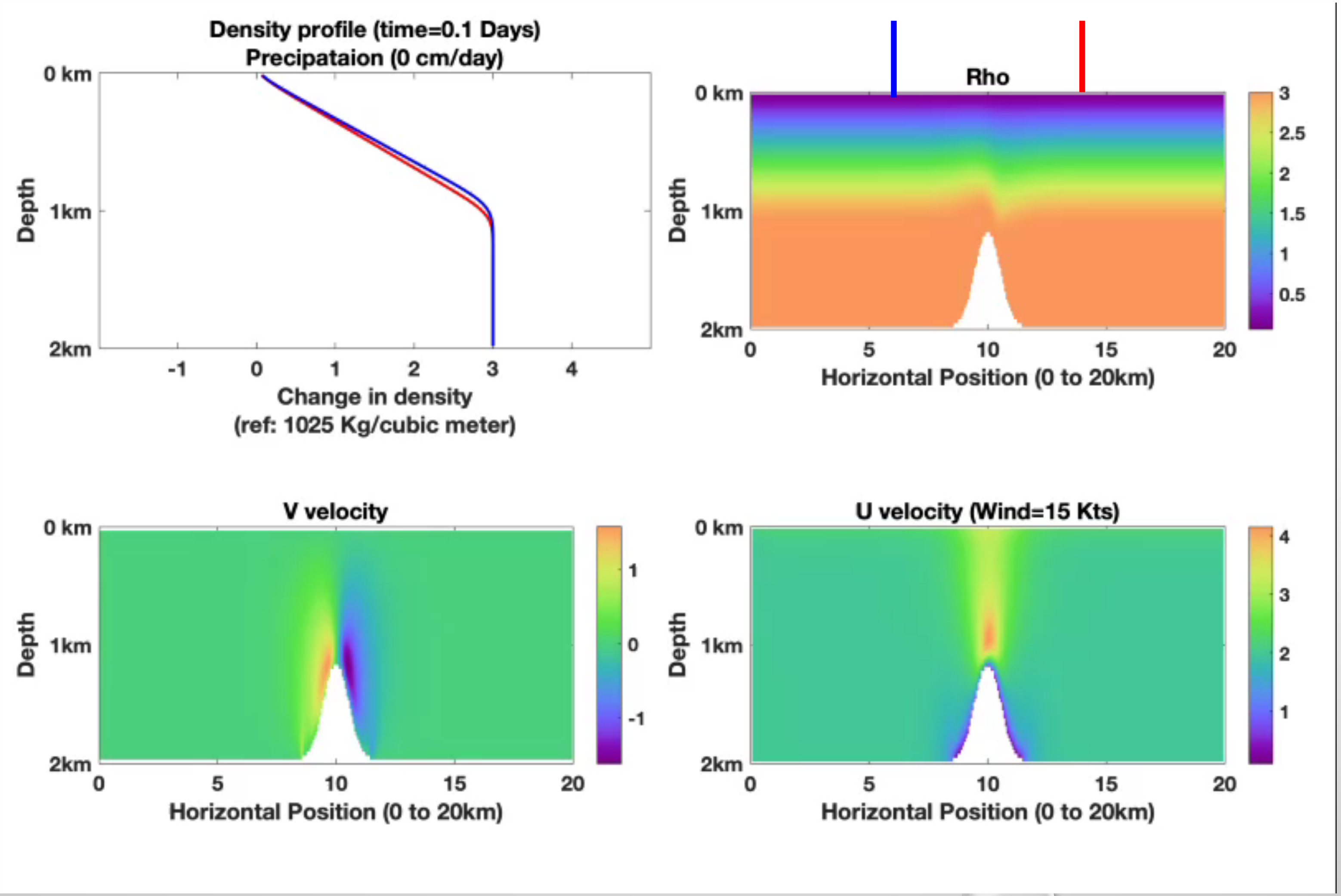
- Q_I : IS THE RATE OF ABSORPTION OF SOLAR RADIATION (W/ $m^{2)}$)

  $Q_I = \max\ [(d_m/d)^2 * \sin\phi * \sin\theta - \cos\ \phi * \cos\theta * \cos(h)$

- Q_B : IS THE UPWARD FLUX OF LONG–WAVE RADIATION (W/m^2)
- Q_L: IS THE UPWARD LATENT HEAT FLUX (W/ m^2)
- Q_S: IS THE UPWARD SENSIBLE HEAT FLUX (W/ m^2)

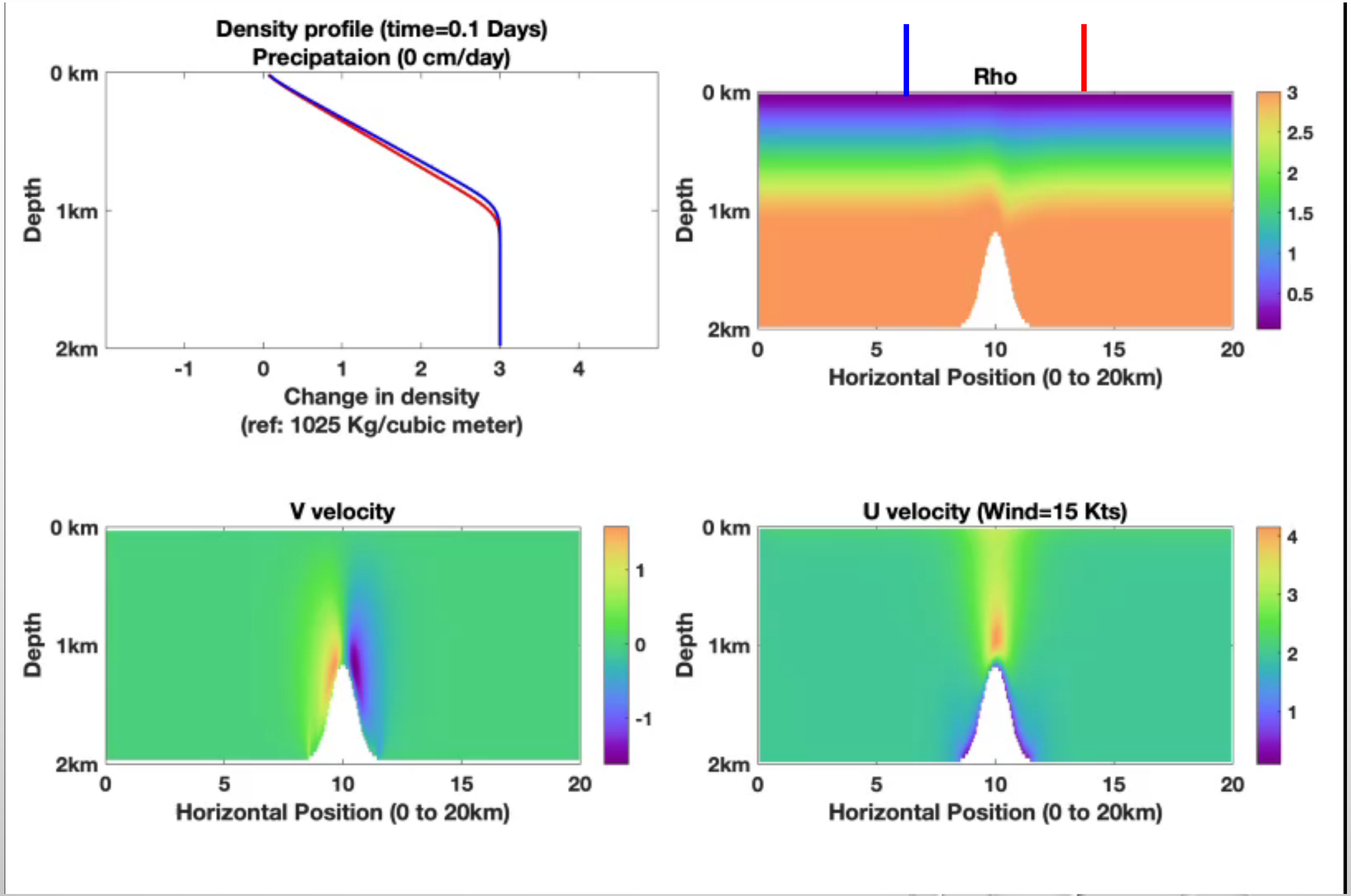


SCENARIO 0:



Density profile (time=0.1 Days)
Precipataion (0 cm/day)
0 km
1km
2km
Depth
-1
0
1
2
3
4
Change in density
(ref: 1025 Kg/cubic meter)
Rho
0 km
1km
2km
Depth
0
5
10
15
20
Horizontal Position (0 to 20km)
3
2.5
2
1.5
1
0.5
V velocity
0 km
1km
2km
Depth
0
5
10
15
20
Horizontal Position (0 to 20km)
1
0
-1
U velocity (Wind=15 Kts)
0 km
1km
2km
Depth
0
5
10
15
20
Horizontal Position (0 to 20km)
4
3
2
1

SCENARIO 1:


Density profile (time=0.1 Days)
Precipataion (0 cm/day)
0 km
1km
2km
Depth
-1
0
1
2
3
4
Change in density
(ref: 1025 Kg/cubic meter)
Rho
0 km
1km
2km
Depth
0
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10
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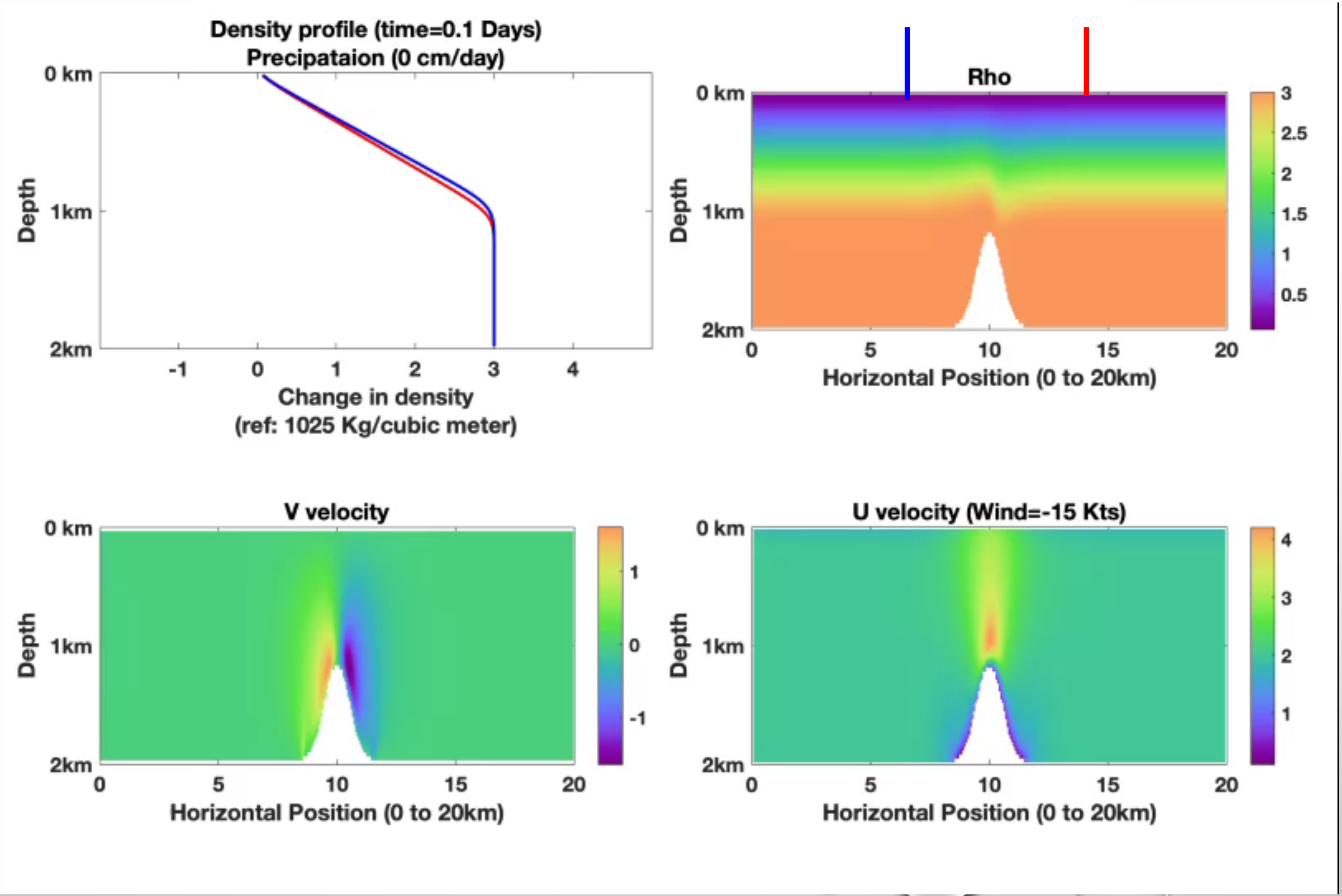
20
Horizontal Position (0 to 20km)
3
2.5
2
1.5
1
0.5
V velocity
0 km
1km
2km
Depth
0
5
10
15
20
Horizontal Position (0 to 20km)
1
0
-1
U velocity (Wind=15 Kts)
0 km
1km
2km
Depth
0
5
10
15
20
Horizontal Position (0 to 20km)
4
3
2
1

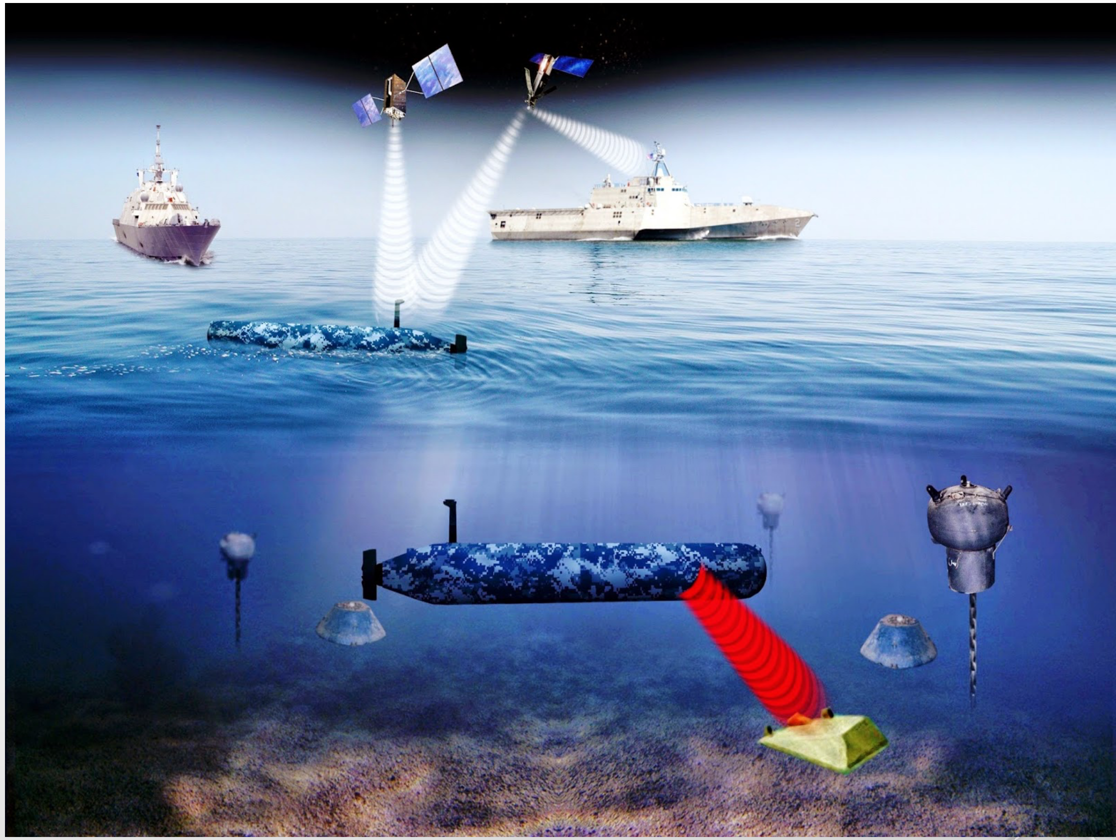
SCENARIO 2



Density profile (time=0.1 Days)
Precipataion (0 cm/day)
0 km
1km
2km
Depth
-1
0
1
2
3
4
Change in density
(ref: 1025 Kg/cubic meter)
Rho
0 km
1km
2km
Depth
0
5
10
15
20
Horizontal Position (0 to 20km)
3
2.5
2
1.5
1
0.5
V velocity
0 km
1km
2km
Depth
0
5
10
15
20
Horizontal Position (0 to 20km)
1
0
-1
U velocity (Wind=-15 Kts)
0 km
1km
2km
Depth
0
5
10
15
20
Horizontal Position (0 to 20km)
4
3
2
1

MOVING FORWARD

- BE ABLE TO APPLY THE MODEL TO SOUND SPEED DEPENDENT VARIABLES (SALINITY TEMP DEPTH)
- DERIVE DISTRIBUTIONS FOR HOW UNCERTAINTY IN INPUT VARIABLES EVOLVE THE SSP UNCERTAINTY OVER TIME
  - DYNAMICALLY ORTHOGONAL EQUATIONS
- INTEGRATE WITH MSEAS WORK ON ACOUSTIC INFERENCE
  - BAYESIAN MACHINE LEARNING
  - DYNAMICALLY ORTHOGONAL EQUATIONS
- EVALUATE CAPACITY OF NEURAL NETWORK TO LEARN CONSTRAINED SCENARIOS
  - IMPROVE SITUATIONAL AWARENESS OF SUBMERGED VEHICLES
  - ADVANCE AUTONOMY OF AUVS



THANK YOU - MSEAS