Mixed-Layer Simulations At OWS Bravo: The Role Of Salinity In The Mixed-Layer Dynamics

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Air-Sea Interaction

\[ z = 0 \]

\[ \text{Air} \]

\[ \text{Sea} \]

\[ I(z) \]

\[ u_w \]

\[ Q \]

\[ (P-E) \]

\[ \rho(z) \]

\[ h \]
Location of OWS Bravo

Source: Lazier, Atmos. Ocean, 1980
GOVERNING EQUATIONS

\[
\frac{\partial \overline{U}}{\partial t} = f \overline{V} - \frac{\partial (u'w')}{\partial z}
\]

\[
\frac{\partial \overline{V}}{\partial t} = -f \overline{U} - \frac{\partial (v'w')}{\partial z}
\]

\[
\frac{\partial \overline{T}}{\partial t} = \frac{1}{\rho_0 c_p} \frac{\partial I}{\partial z} - \frac{\partial (\overline{T}'w')}{\partial z}
\]

\[
\frac{\partial \overline{S}}{\partial t} = -\frac{\partial (s'w')}{\partial z}
\]

At OWS Bravo \( f = 1.2128 \times 10^{-4} [1/s] \), \( \rho_0 = 1027 [kg/m^3] \)
and \( c_p = 4190 [J/kg K] \).
BOUNDARY CONDITIONS

Surface flux conditions at \( z = 0 \):

\[
\overline{u'w'_0} = -\frac{\tau_x}{\rho_0}, \quad \overline{v'w'_0} = -\frac{\tau_y}{\rho_0}
\]

\[
\overline{T'w'_0} = -\frac{Q}{\rho_0 c_p}
\]

\[
\overline{s'w'_0} = -\overline{S}_0 (E - P)
\]

Bottom boundary conditions at \( z = -D \):

\[(\overline{U}, \overline{V}) \rightarrow (0, 0)\]

\[\overline{T} \rightarrow \overline{T}_\infty\]

\[\overline{S} \rightarrow \overline{S}_\infty\]
EXTERNAL PARAMETERIZATIONS

Equation of State: (Friedrich & Levitus, J.P.O., 1972)

\[ \sigma(T, S) = C_1 + C_2 T + C_3 S + C_4 T^2 + C_5 ST + C_6 T^3 + C_7 ST^2 \]

\[ C_1 = -7.2169 \times 10^{-2}, \quad C_2 = 4.9762 \times 10^{-2}, \quad C_3 = 8.0560 \times 10^{-1} \]
\[ C_4 = -7.5911 \times 10^{-3}, \quad C_5 = -3.0063 \times 10^{-3} \]
\[ C_6 = 3.5187 \times 10^{-5}, \quad C_7 = 3.7297 \times 10^{-5} \]
\[ \alpha = -\frac{1}{\rho_0} \frac{\partial \sigma}{\partial T}, \quad \beta = \frac{1}{\rho_0} \frac{\partial \sigma}{\partial S} \]


\[ \frac{I(z)}{I_0} = Re^{z/l_1} + (1 - R)e^{z/l_2} \]

At OWS Bravo the water optical type is very clear.

\[ R = 0.4, \quad l_1 = 5m, \quad l_2 = 40m \]
Observed Mixed-Layer Depth
HEAT AND SALT BALANCE

Integrating the temperature and salinity equations from $z = -D$ to $z = 0$ gives

$$\frac{d}{dt} \int_{-D}^{0} \overline{T} \, dz = \frac{1}{\rho_0 c_p} [Q + I_0]$$

$$\frac{d}{dt} \int_{-D}^{0} \overline{S} \, dz = -\overline{S}_0 [P - E]$$

Integrating again in time yields

$$\int_{-D}^{0} \overline{T}(t) \, dz - \int_{-D}^{0} \overline{T}(t = 0) \, dz = \frac{1}{\rho_0 c_p} \int_{0}^{t} [Q + I_0] \, dt$$

$$\int_{-D}^{0} \overline{S}(t) \, dz - \int_{-D}^{0} \overline{S}(t = 0) \, dz = -\overline{S}_0 \int_{0}^{t} [P - E] \, dt$$
Simulated vs Observed Heat & Salt Budgets
Simulated vs Observed Sea-Surface Temp. & Mixed-Layer Depth

red line: simulation using Bulk Model
blue line: simulation using Turbulence Closure Model
SUMMARY

- 1-D models cannot simulate salinity well at OWS Bravo
- simulations of SST and MLD improve as the salinity is more realistically specified
- salinity is an important factor controlling mixed-layer properties during the cooling phase (winter - spring)
- for period 1964-1965, max MLD is 300m and min SST is 3°C
  for period 1969-1971, max MLD is 200m and min SST is 2°C
- the difference in max MLD and min SST is mainly a salinity effect