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Turbulent Vertical Velocities in Labrador Sea Convection

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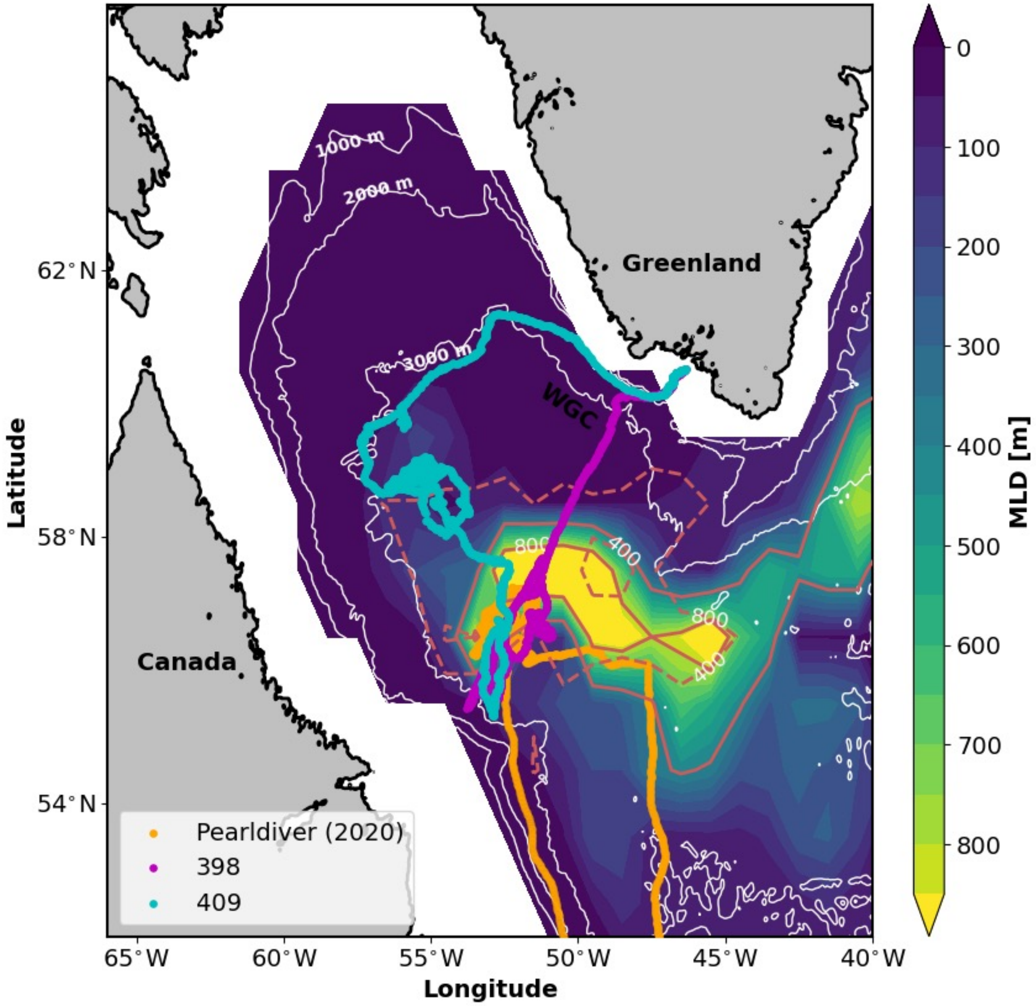
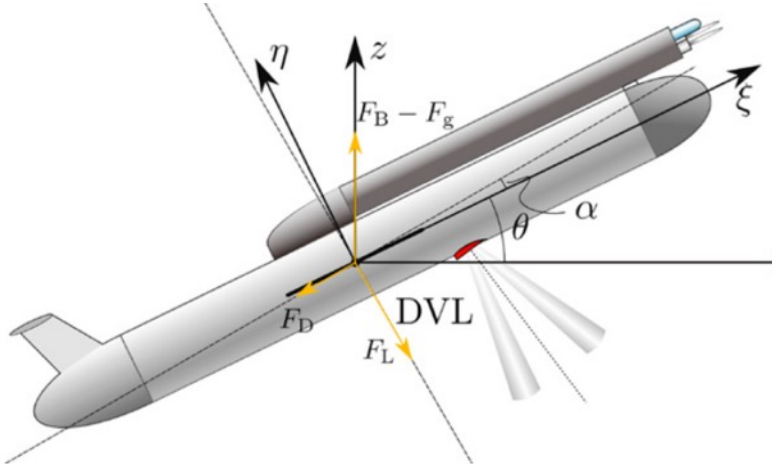
TERIFIC

Winter Glider Deployments in the Labrador Sea





$$w = w_m - w_g$$

Vertical water velocity

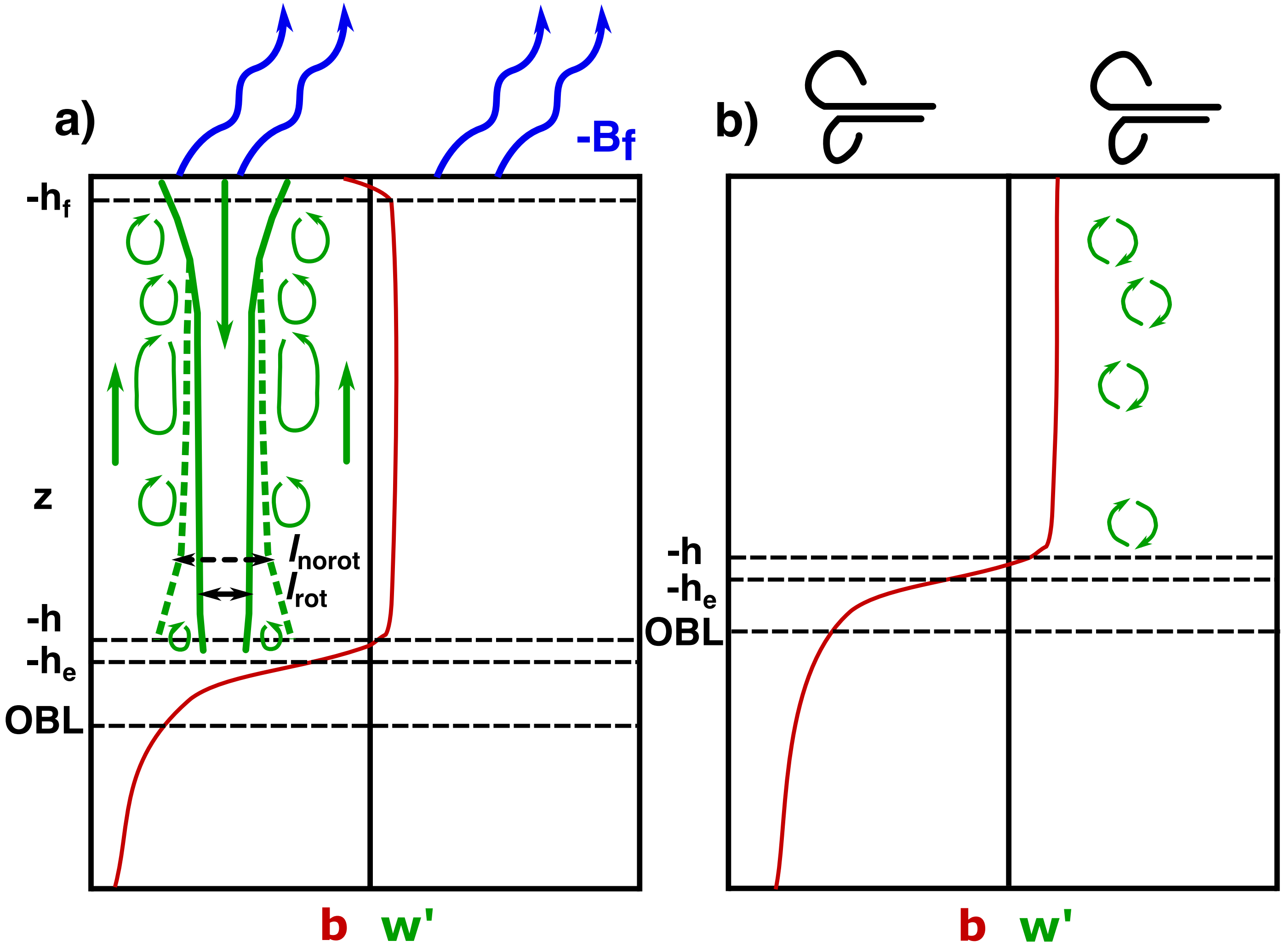
Measured glider vertical velocity (pressure sensor)

Modeled glider flight speed

Merckelbach et al. (2010)
Frajka-Williams et al. (2011)

Convective and wind-driven vertical velocities (w’)

1. Surface buoyancy loss
2. Generation of convective plumes with large w’ (3D then 2D turbulence)



1. Winds
2. Shear-driven turbulence

Convective and wind-driven vertical velocities (w’)

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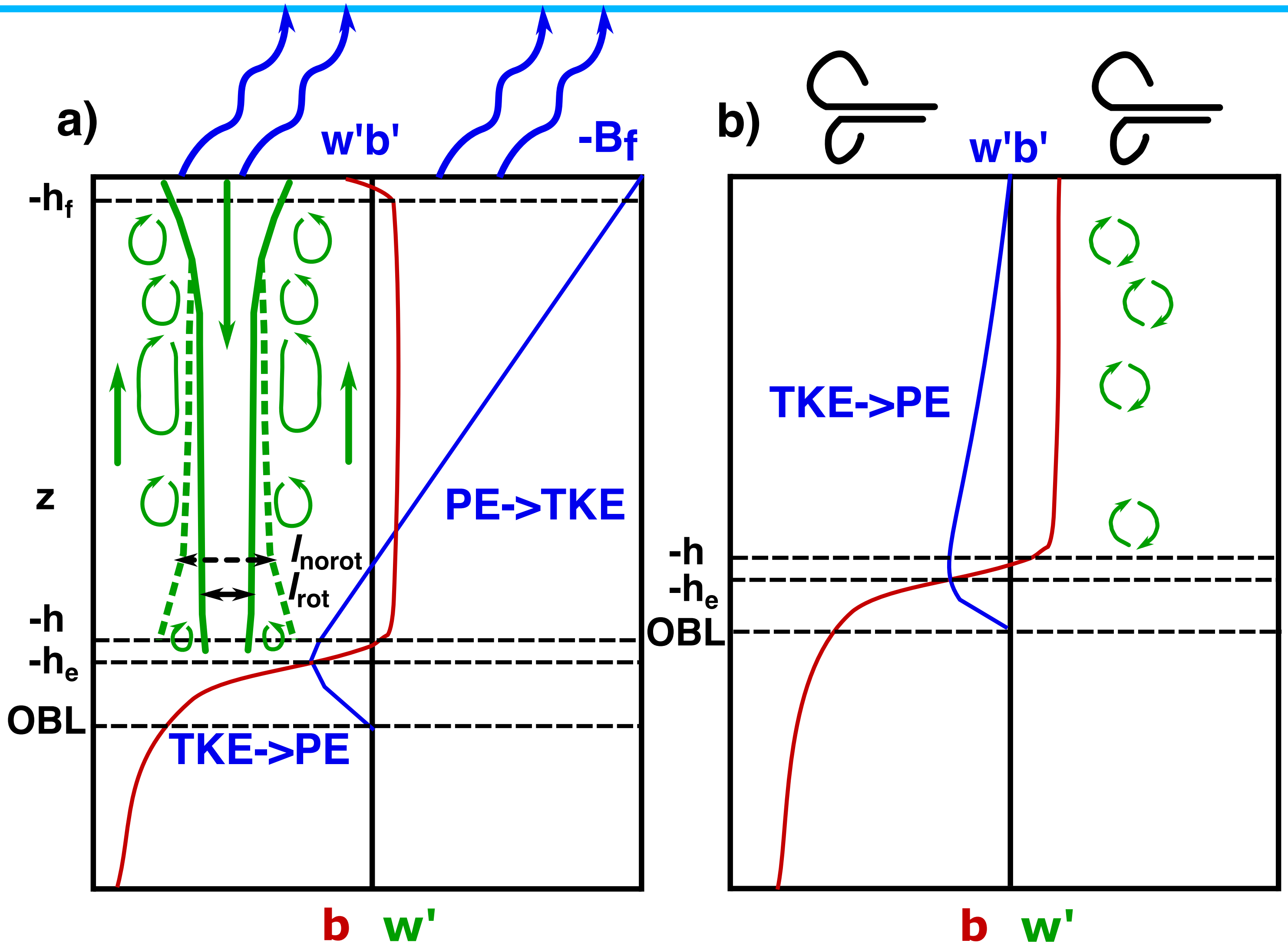
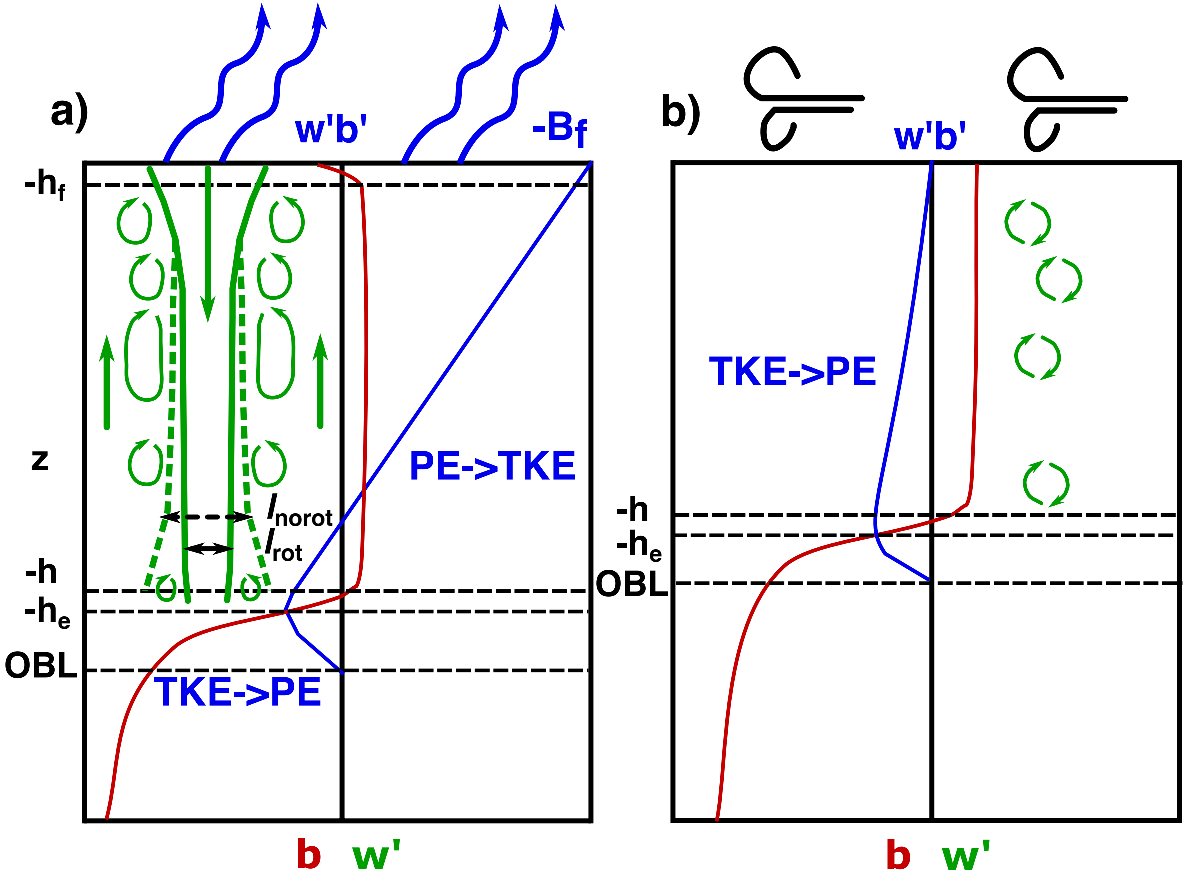
1. Surface buoyancy loss
2. Generation of convective plumes with large w’ (3D then 2D turbulence)
3. Positive buoyancy flux (negative at depth with entrainment)



1. Winds
2. Shear-driven turbulence
3. Mixed MLD (PE increases)

Convective and wind-driven vertical velocities (w')



1) **What are the plume characteristics?**
   - → Compare with other convective sites
   - → Buoyancy flux from plumes

2) **Is w' following the Atmospheric Boundary Layer scalings?**
   - → Convective vs wind-forced turbulence
   - → Rotational w vs non-rotational w

3) **How does the buoyancy flux evolve at various stages of convection?**
   - → θ vs S on σ for restratification (Clément et al., 2023)
   - → w'b' at entrainment depth (in ML models, KPP,...)

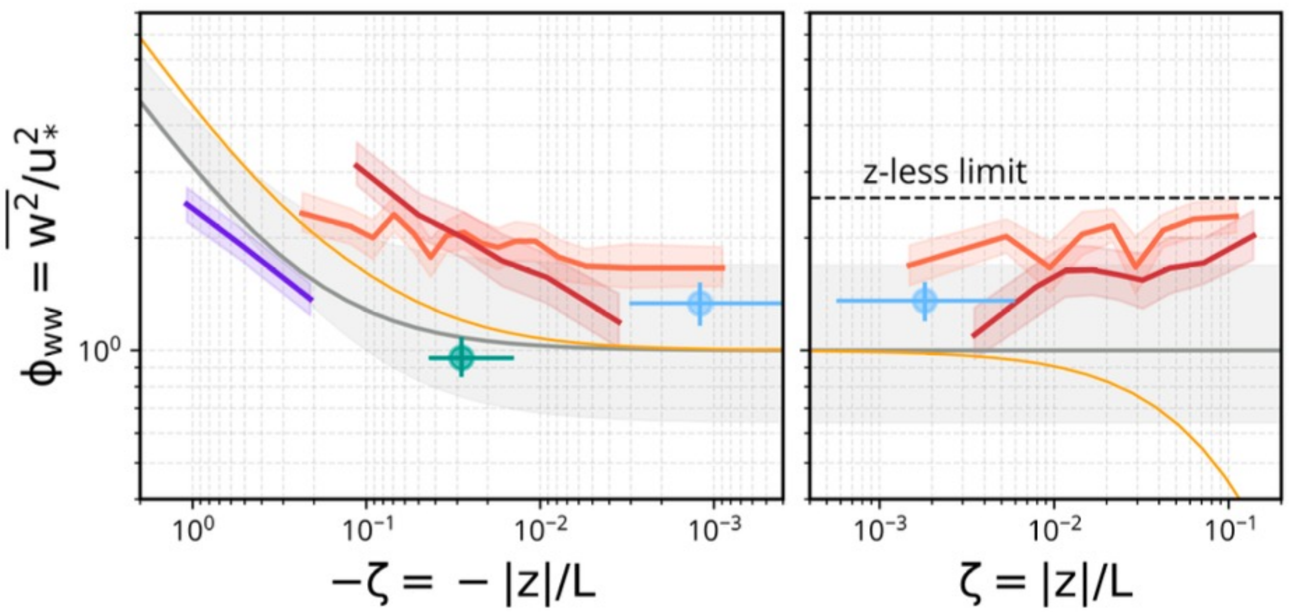
Monin-Obukhov scaling in thesurface layer

Empirical evidence predicts that w'^2 should only depend on the distance to the surface |z|, the friction velocity, u_*, and the Obukhov lengthscale L.

$w'^2/u^2_* \sim z/L$

$L \sim -u^3_*/B_0$:

- stable (L>0)
- unstable (L<0, with B_0>0)



Zheng (2023)

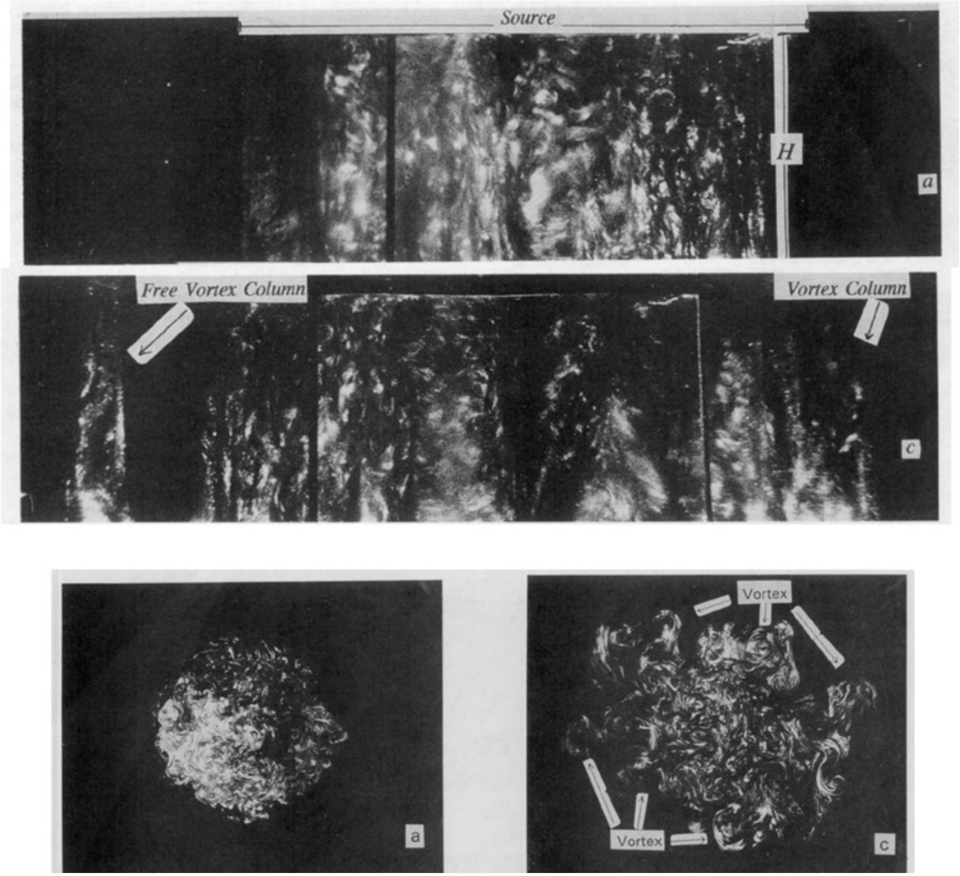
Rotational effect on convection

- A smaller Ro* $(=B_0/f^3h^2)^{1/2}$ means a larger effect of rotation
- A larger Ro* means larger eddies around convective plumes/chimneys

$w^*_{rot} \sim (B_0/f)^{1/2}$

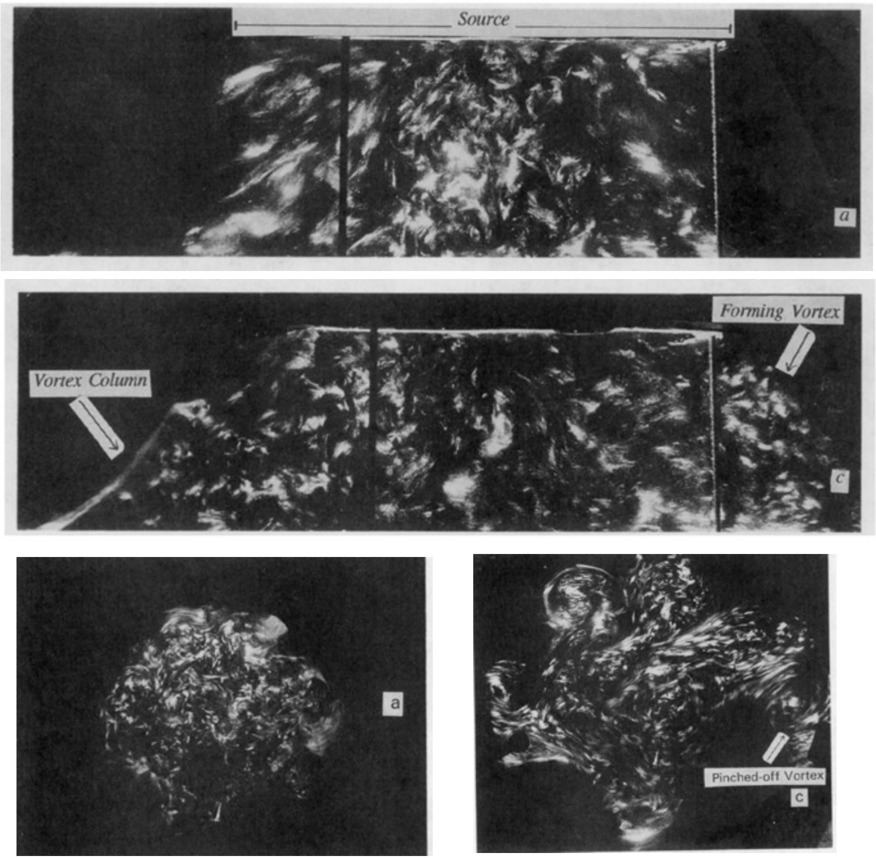
Side view

Top view



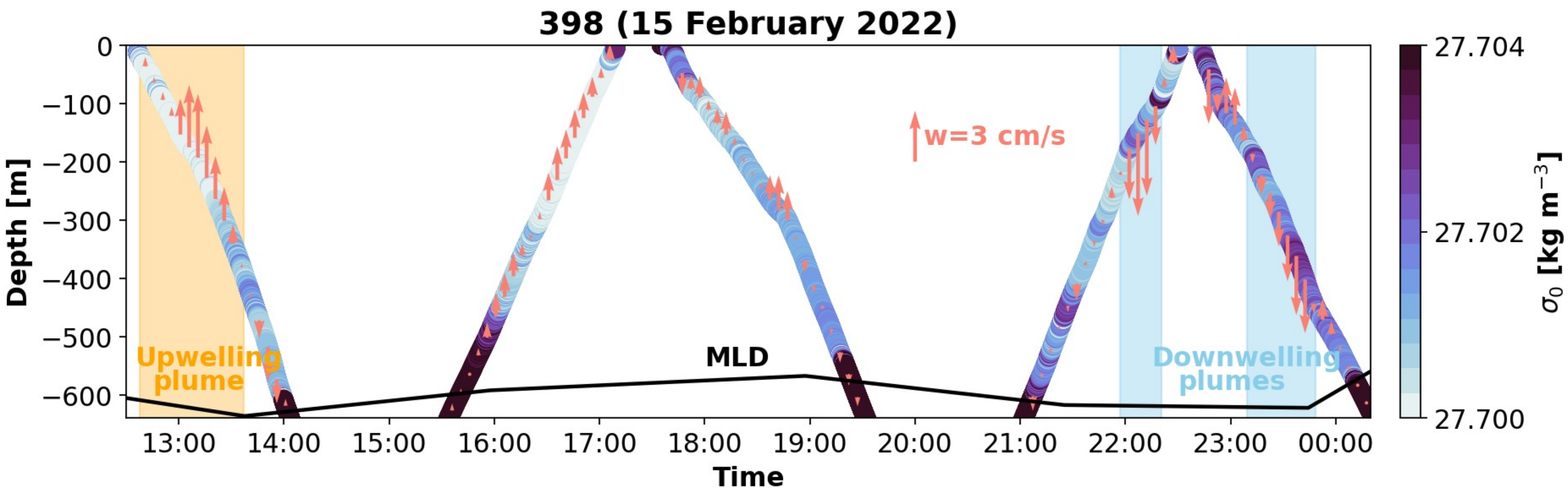
Increase Ro*

$w^*_{norot} \sim (B_0h)^{1/3}$



Maxworthy and Narimousa (1994)

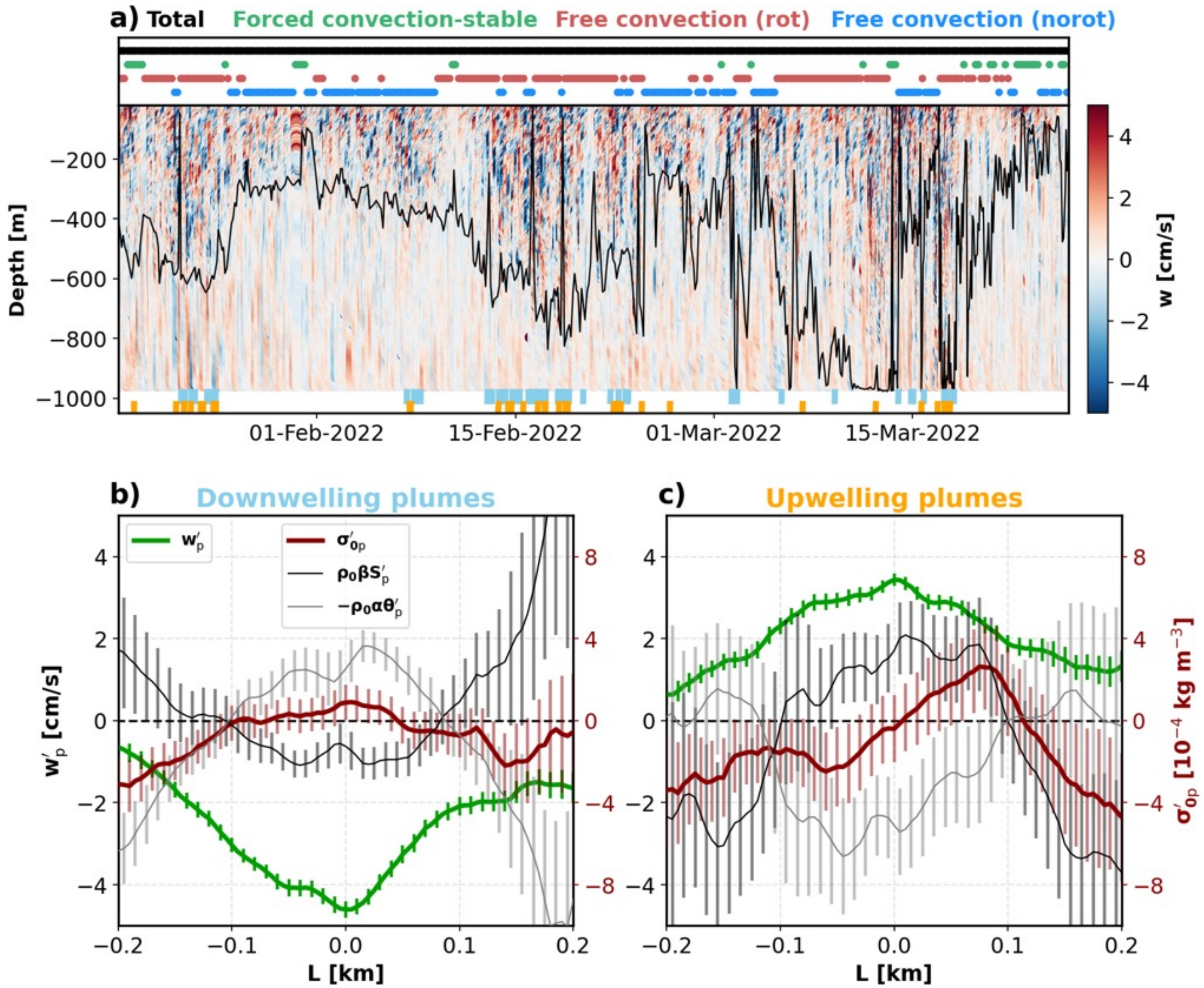
Plume detection



- Convective periods: Days with $P_{|w|>2cm/s}$>10%
- Convective plumes: |w|>2cm/s & L>150 m

Margirier et al. (2017)

Plume characteristics



- Downwelling plumes have a diameter of 640 m (covered in ~1 hour by gliders).
- They are cooler and denser in their center.
- Composite over ~150 downwelling plumes:

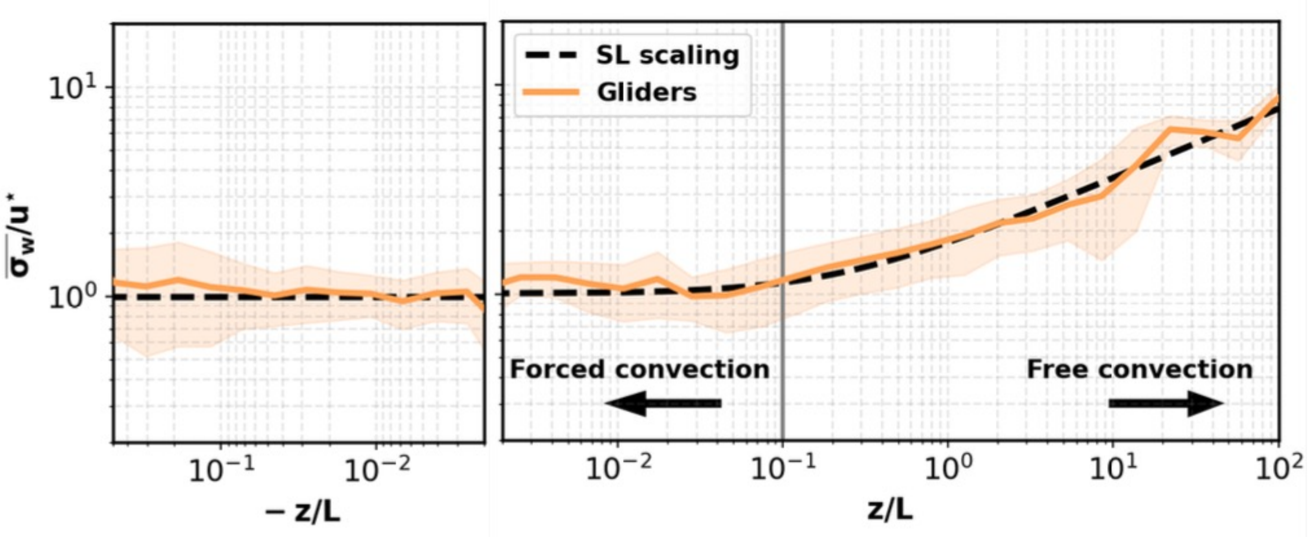
$w' = 4.6$ cm s^{-1} $\quad \sigma' = 4 \times 10^{-4}$ kg m^{-3}

$(w'b')_{plumes} = 1.8 \times 10^{-7}$ $m^2 s^{-3}$

$a_p = 2\%$

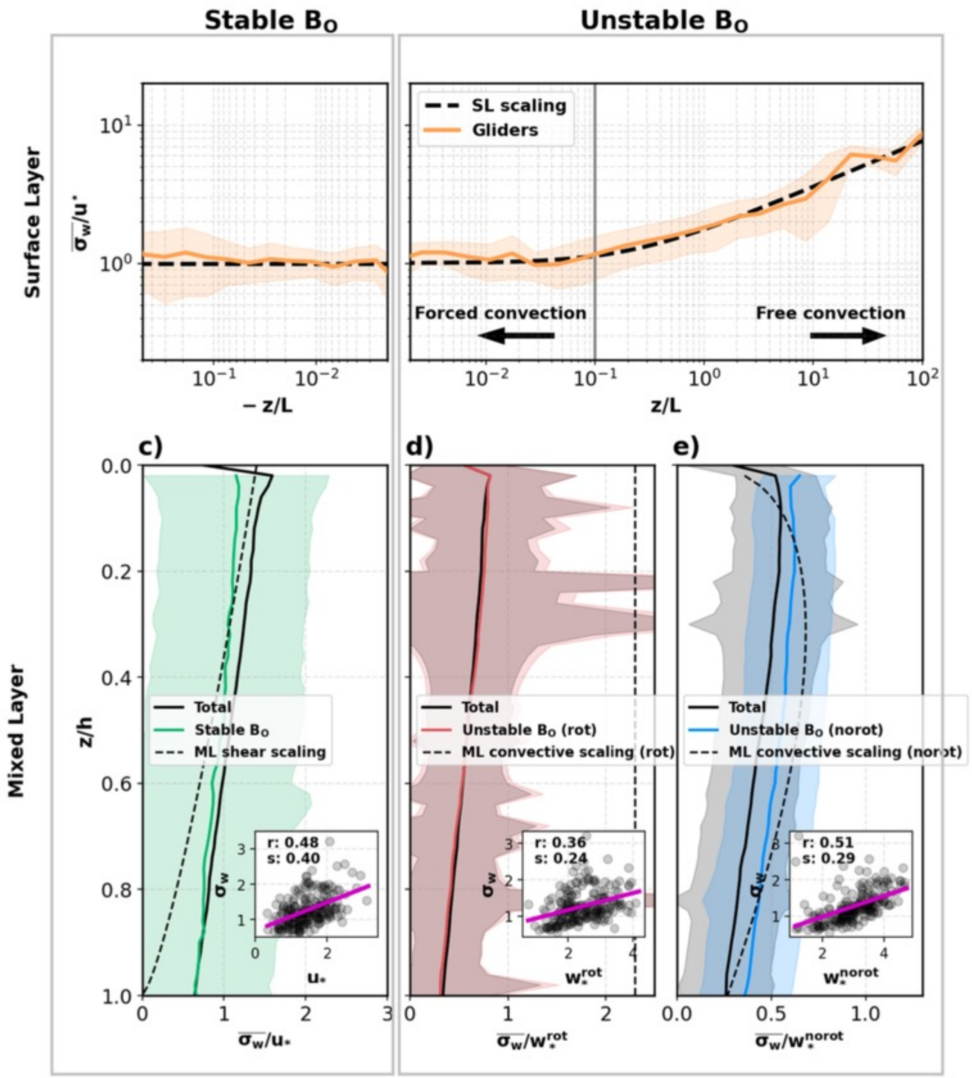
$$\overline{w'b'} = -\kappa \frac{\partial \bar{b}}{\partial z} - ap(w'b')_{plumes}$$

Scalings of w’



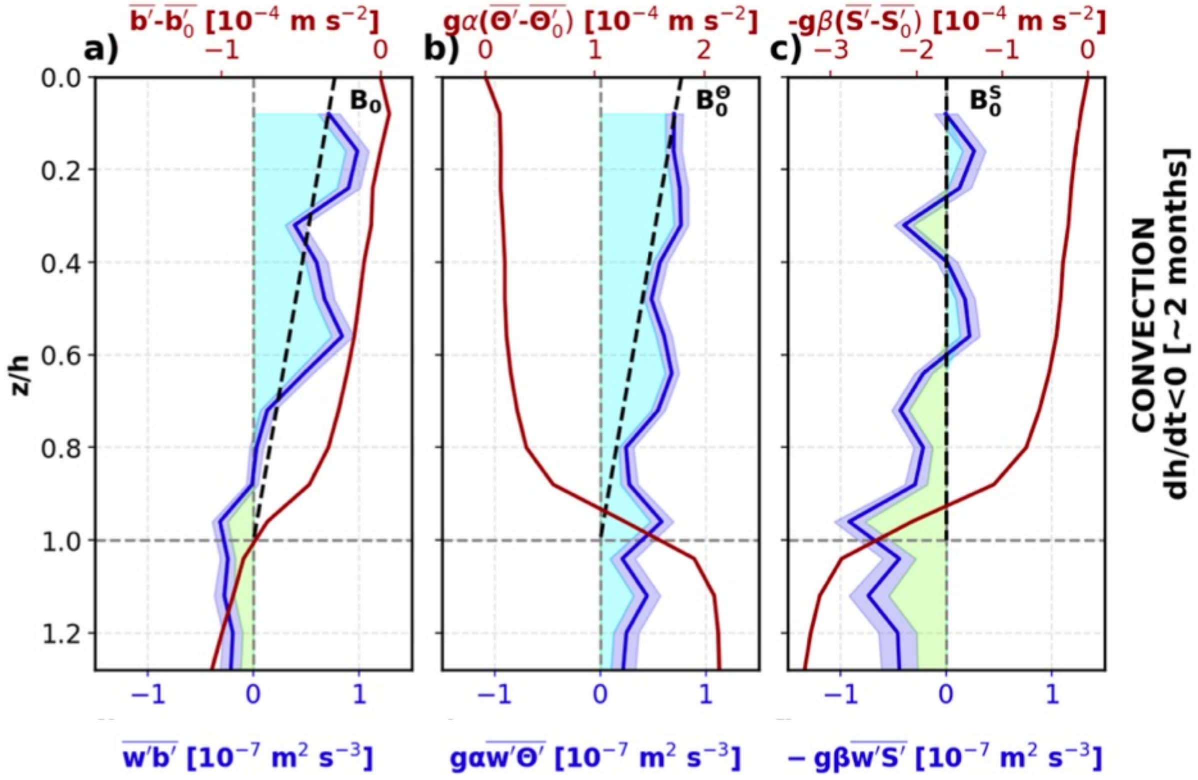
- $(w'^2)^{1/2}$ agrees with ASL predictions, without an important effect from waves and Langmuir turbulence.

Scalings of w'



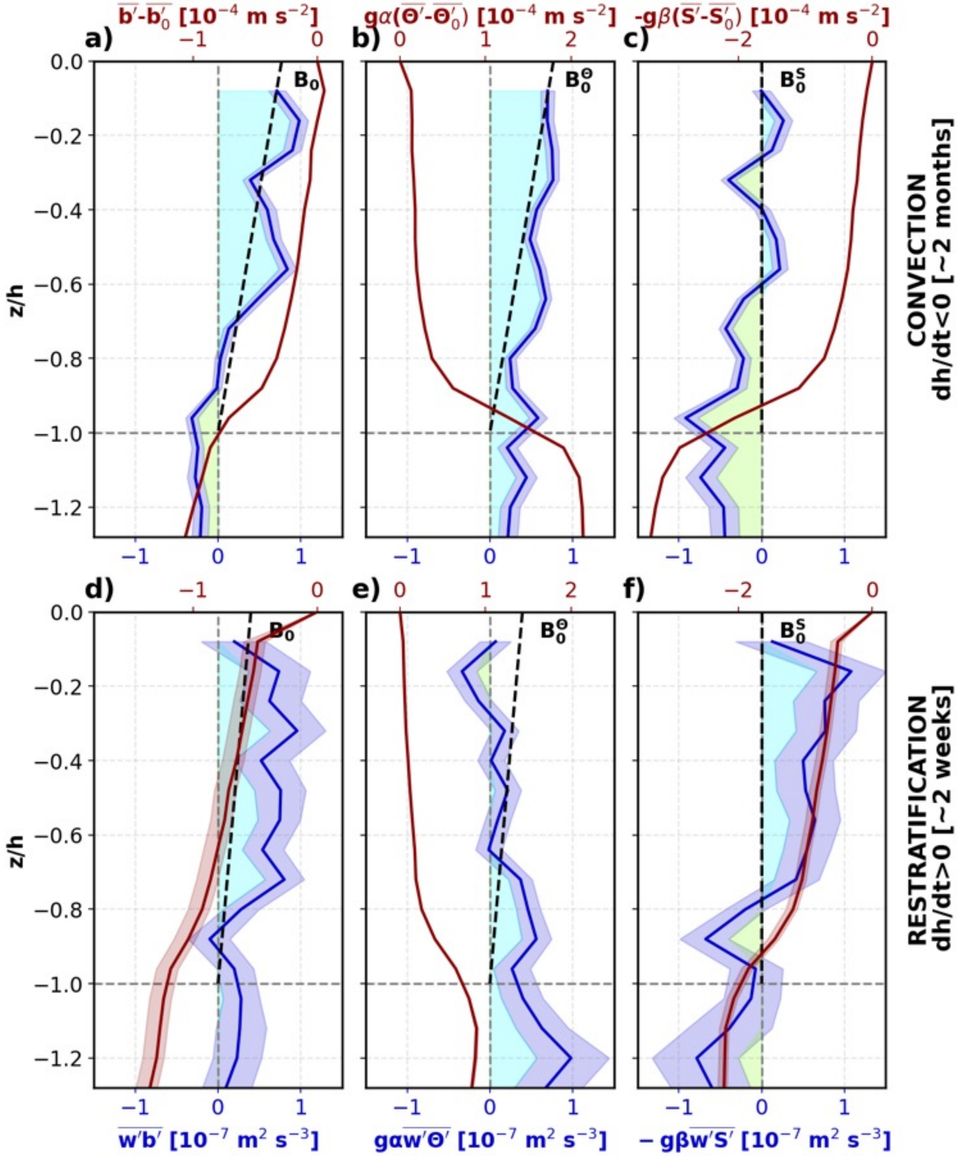
- $(w'^2)^{1/2}$ agrees with ASL predictions, without an important effect from waves and Langmuir turbulence.
- Choosing norot brings the ratio close to ABL scaling and deepens the maxima.
- In late March, the scaling follows wind-driven turbulence.

Buoyancy flux (w'b') estimates



- w'b' is consistent with surface buoyancy loss (B_0).
- w'b'>0 in the ML:
  - ➢ due to w'Θ' (during convection, dΘ/dz<0)
- Entrainment around h (with w'b<0) is due to the injection of warm and salty waters.

Buoyancy flux (w’b’) estimates



- w’b’ is consistent with surface buoyancy loss (B_0).
- w’b’>0 in the ML:
  - ➢ due to w’ϴ’ (during convection, dϴ/dz<0)
  - ➢ **due to w’S’ (during restratification, dS/dz<0)**
- Entrainment around h (with w’b<0) is due to the injection of warm and salty waters.

Conclusions

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- **Vertical velocity** in the oceanic deep convective region **follows scalings from the Atmospheric Surface/Boundary Layers** under wind and buoyancy forcing.

- **Convective plumes are identified** from vertical velocity, indicating that non-rotational convection seems to prevail.

- **Positive vertical buoyancy** flux occurs during convection, **initially due to atmospheric cooling** and **then due to freshwater flux during restratification**.

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