Stochastic modeling of transient Ekman flow at arbitrary Reynolds number driven by horizontal bottom wall oscillation

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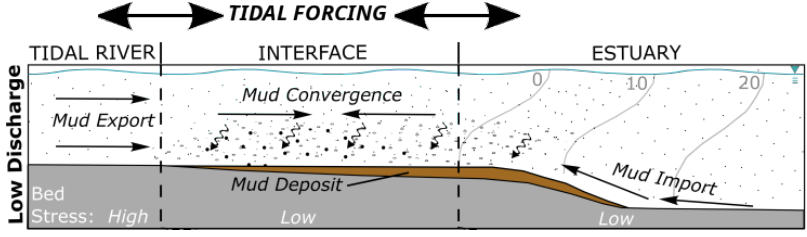


Rotating–oscillating boundary layers

- Oscillatory mean pressure gradients
- Oscillatory wind shear at sea surface
- Tidal flows in the atmosphere and ocean
  e.g. **estuarine flows**



NASA Earth Observatory, Thames river estuary



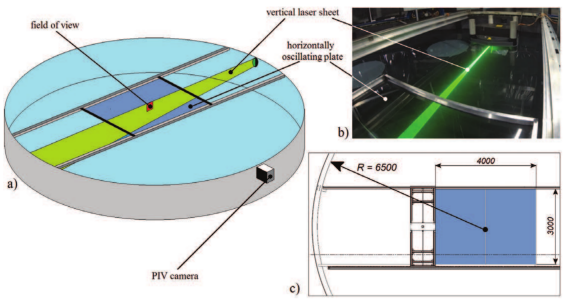
Adapted from: Ogston *et al.* (2017) *Oceanography* **30**(3):22–33

Ekman–Stokes boundary layer (ESBL) reference experiment I

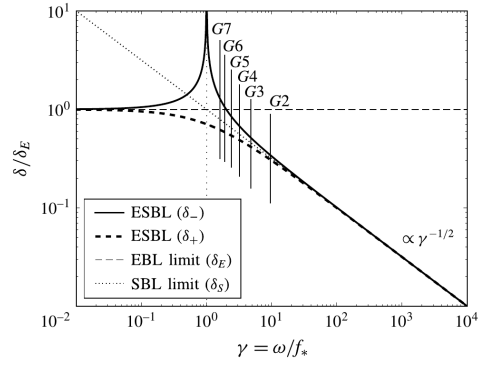
Boundary-layer resonance manifests itself by an 'eruption' of $\delta_- \to \infty$ for $\omega \to f$.

$$\delta_\pm = \sqrt{2\nu/|f \pm \omega|} \qquad \delta_\mathsf{E} = \sqrt{2\nu/f} \qquad \delta_\mathsf{S} = \sqrt{2\nu/\omega}$$

Coriolis platform, Grenoble, France



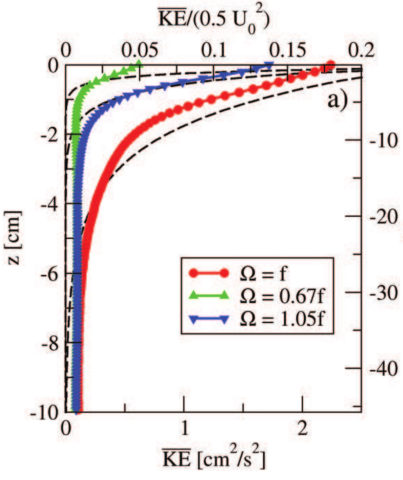
From: Vincze, Fenyvesi, M.K. *et al.* (2019) *EPL* **125**:44001

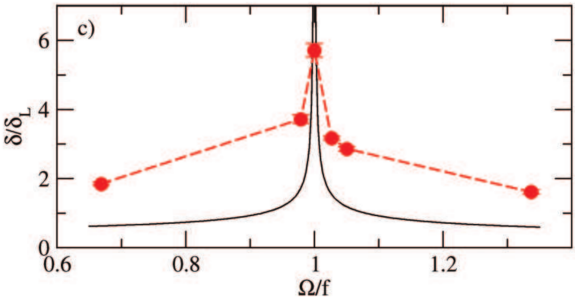


From: Ghasemi, M.K., Will & Harlander (2018)
J. Fluid Mech. **853**:111–149

Ekman–Stokes boundary layer (ESBL) reference experiment II

boundary layer resonance ('eruption')

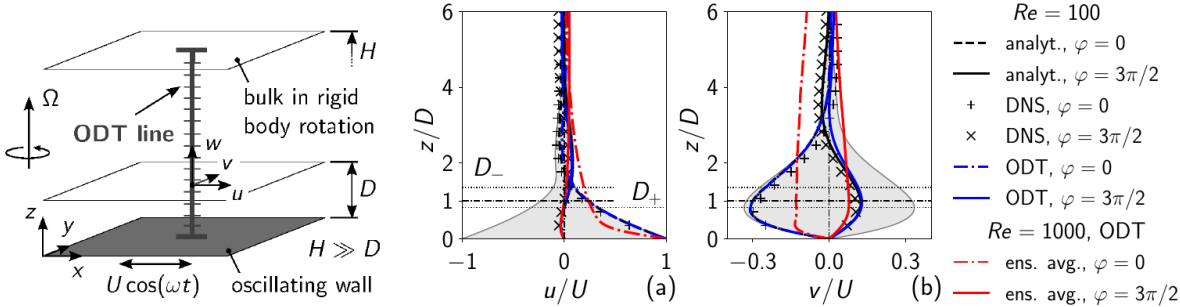




Vincze, Fenyvesi, M.K. *et al.* (2019) *EPL* **125**:44001

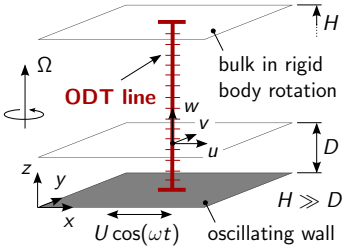
Horizontal velocities from a 'one-dimensional turbulence' (ODT) model

ensemble-averaged u and v for two phases $\varphi = 0$ and $3\pi/2$

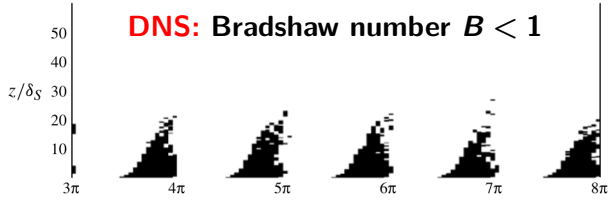


ODT (— laminar, — turbulent): M.K. & H.S. (2020) *Proc. Appl. Math. Mech.* **20**:e202000127
Laminar DNS (+, ×) and theory (—): Ghasemi, M.K., *et al.* (2018) *J. Fluid Mech.* **853**:111–149
Vincze, Fenyvesi, M.K. *et al.* (2019) *EPL* **125**:44001

Spatio-temporal evolution of turbulence indicators

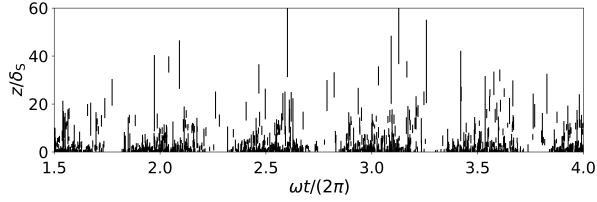


Qualitative agreement between ODT and DNS.



From: Salon & Armenio (2011) *J. Fluid Mech.* **684**:316–352, Fig. 6(a)

ODT: stochastically sampled 'eddy events'



Summary

- **'One-dimensional turbulence' (ODT)** is a *physics-based* stochastic turbulence model that aims to resolve *all* relevant scales in a reduced dimensional setting.
- ODT has predictive and **regime-spanning modeling capabilities**.
- Some relevant **transient and finite-Re effects** in oscillatory Ekman boundary layers are captured.
- Laminar–turbulent transitions are not fully captured. The model prefers **fully developed turbulence** yielding a lower tendency for laminarization.
- Utilization of ODT as **advanced SGS (wall) model** may nevertheless improve the *bulk–surface coupling* at affordable cost.