Adaptation of the vertical resolution in the mixed layer for HYCOM

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Initial conditions

- Profile of temperature at the beginning of the simulation and zoom over the first 200m
- Representative of a winter stratification in the north eastern Atlantic ocean at mid-latitude
- 1m resolution
- Only the forcings, KPP and hybgen are activated
The problem

- Parameters used to define z-levels in HYCOM:
  - \( h_1 \) (dp00): minimum thickness of the first layer;
  - \( h_{\text{max}} \) (dp00x): z-level spacing maximum thickness;
  - stretch (dp00f): stretching factor.

Simulation during 20 days
- Forcings:
  - wind=20 m/s;
  - air temperature=1°C;
  - net radiative flux=0W/m2
- 32 hybrid layers
- \( h_1 = 1.01 \text{m}, h_{\text{max}} = 1.41 \), stretch=1.04

Difference in SST: 0.3°C!
The mixed layer is poorly represented
Solution: Adaptive vertical resolution

- **Determination of the mixed layer depth** $h_{\text{mix}}$: depth at which a change from the surface density of 0.025 kg/m$^3$ has occurred. If mixed layer=1 layer, it is extended to the last z-level from the previous time step, $N_z=$number of z-levels;

- **Calculation of the coefficients**:
  - if $h_{\text{mix}} < 20$ m : $h_1 = 1.01$ m, otherwise $h_1 = 3$ m.
  - stretch is determined to verify the equation:
    $$h_{\text{mix}} = h_1 \frac{1 - \text{stretch}^{N_z}}{1 - \text{stretch}}$$
  - $h_{\text{max}}=500$m.

- **Filtering**: to avoid strong modifications of the vertical grid
  $$h_1^{n+1} = (1 - \alpha) \times h_1^n + \alpha \times h_1$$
  and
  $$\text{stretch}^{n+1} = (1 - \alpha) \times \text{stretch}^n + \alpha \times \text{stretch}$$
  with \( \alpha = \frac{dt}{K} \)

K=10000s, dt=100s
## Experiments and atmospheric forcings

<table>
<thead>
<tr>
<th>Experiments</th>
<th>Number of layers</th>
<th>Vertical coordinate</th>
<th>$h_1$ (m)</th>
<th>$h_{\text{max}}$ (m)</th>
<th>stretch</th>
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</table>

<table>
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<tr>
<th>Case</th>
<th>Air temperature (°C)</th>
<th>Wind (m/s)</th>
<th>Net radiative flux (W/m²)</th>
<th>Short-wave flux (W/m²)</th>
<th>Number of days</th>
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<tbody>
<tr>
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</tbody>
</table>

June 2009  
LOM 2009, Miami, Florida  
Cécile Renaudie
Results for the convective case after 20 days
Results for the convective case throughout time

\[ \|T\|^2 = \frac{1}{H_{tot}} \sum (T_{ref}(i) - T_{exp}(i))^2 h_i \]
Results for the wind-mixing case after 20 days
Results for the wind-mixing case throughout time
The realistic case

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Results for the realistic case throughout time
Conclusions

- EXP-CNA: poor representation of the mixed layer as it deepens, growing error in SST and in mixed layer structure;
- EXP-CG: better solution in convective cases, but not adapted to shallow mixed layers;
- EXP-A: improves the distribution of geopotential levels in the mixed layer;
- Still some improvements to make:
  - Sensitivity to mixed layer definition;
  - Sensitivity to the damping rate: it could depend on the forcings;
  - 2 and 3 dimensions: still some problems with boundary conditions.
First results in 3D

EXP-CNA

31st May 2005

EXP-A