WAVETRISK-OCEAN

an adaptive dynamical core for ocean modelling

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Collaborators

- Florian Lemarié *(co-author)*
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- Thomas Dubos *(WAVETRISK)*
  LMD, École Polytechnique, France
- Matthias Aechtner *(contributed to shallow water code)*
  Former PhD student

WAVETRISK adaptive 3D atmosphere dynamical core

(Credit: NASA Apollo 17 mission)

1. Shallow water equations on the plane using TRISK discretization.

WAVETRISK adaptive 3D atmosphere dynamical core

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2. Shallow water equations on the sphere using TRISK discretization *(Icosahedral C-grid)*.

WAVETRISK adaptive 3D atmosphere dynamical core

(Credit: NASA Apollo 17 mission)

3. 3D hydrostatic extension using DYNAMICO approach, horizontal adaptivity.

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4. Lagrangian vertical coordinates *(PPR conservative remapping)*.

WAVETRISK-OCEAN adaptive hydrostatic ocean model

(Credit: NASA Apollo 17 mission)

1. Incompressible version of WAVETRISK for ocean modelling.

WAVETRISK-OCEAN adaptive hydrostatic ocean model

(Credit: NASA Apollo 17 mission)

2. Volume penalization for coastline boundary conditions *(shallow water model)*.

WAVETRISK-OCEAN adaptive hydrostatic ocean model

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3. Volume penalization for bathymetry in CROCO *(Debreu, Kevlahan, Marchesiello 2020, Ocean Modelling)*.

(Credit: NASA Apollo 17 mission)

4. Barotropic–baroclinic mode splitting *(implicit free surface)*.

WAVETRISK-OCEAN adaptive hydrostatic ocean model

(Credit: NASA Apollo 17 mission)

5. Vertical diffusion with TKE closure, surface forcing of velocity and buoyancy.

Approximations of WAVETRISK-OCEAN

- Hydrostatic
- Simple Boussinesq
  (exactly incompressible $\rho_{pot} = \rho - \rho_0 g z / c_s^2 \approx \rho$).
- Hamiltonian-based inhomogeneous multilayer shallow water equations *(Ripa 1993)*.
- Conservative remapping *(Engwirda and Kelly 2016)*.
- Barotropic–baroclinic mode splitting
  (implicit free surface, adaptive multilevel method for elliptic problem).
- Linear equation of state.
- Vertical diffusion.
  (TKE closure as in NEMO/CROCO.)
- Volume penalization of coastlines.
  (no-slip boundary conditions.)

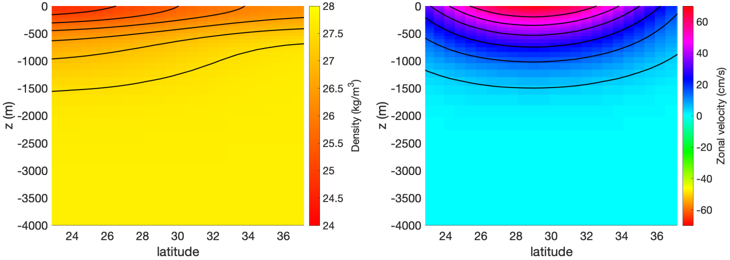
Dynamical equations

inertial mass *(layer heights)*	$\partial_t \mu_{ik} + \delta_i U_{ek} =$	$K_\mu D_\phi \mu_{ik}$
mass-weighted buoyancy	$\partial_t \Theta_{ik} + \delta_i(\theta^*_{ek} U_{ek}) =$	$K_\Theta D_\phi \Theta_{ik},$
velocity	$\partial_t v_{ek} + \delta_e B_{ik} - \theta^*_{ek}\delta_e \overline{\Phi_{il}}^k + (q_{ek} U_{ek})^\perp_e =$	$K_\delta D_\delta v_{ek} + K_\omega D_\omega v_{ek}$
		horizontal diffusion

$\mu_{ik} = \rho_0 \Delta z_{ik}$	inertial mass
$\theta_{ik} = 1 - \rho_{ik}/\rho_0$	buoyancy
$U_{ek} = \overline{\mu_{ik}}^e v_{ek}$	horizontal mass flux

Unstable baroclinic jet *(Soufflet et al 2016)*

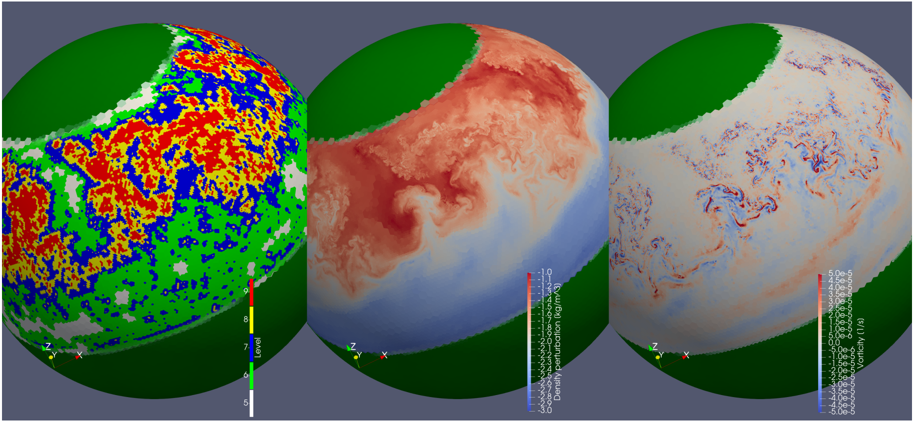
- Realistic test with TKE vertical diffusion model and 60 vertical layers.
- Localized turbulence is a good test of adaptivity.
- Spherical harmonic energy spectra computed using `shtools`.



density zonal velocity

Initial conditions (zonal averages).

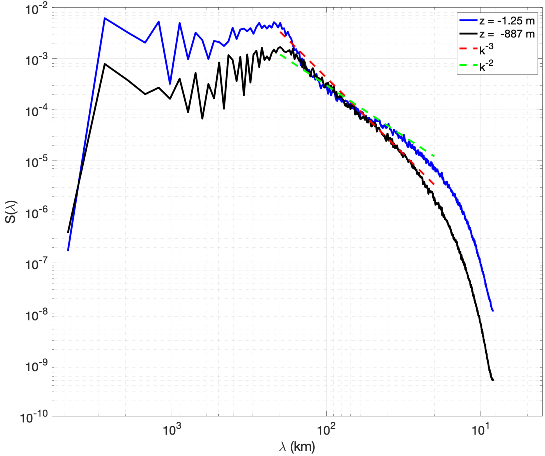
Unstable baroclinic jet *(Soufflet et al 2016)*



adaptive grid *(5 levels)* density perturbation vorticity

Baroclinic turbulence in top layer.

Unstable baroclinic jet *(Soufflet et al 2016)*



Energy spectrum at surface and at -897 m.

Conclusions: WAVETRISK-OCEAN

- DYNAMICO-based 3D hydrostatic incompressible Boussinesq model.

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Ongoing work

- Adapt vertical grid by optimizing target grid *($r-$adaptivity)* or de-activating some vertical layers *(dormant layers)*.
- Implement penalization of bathymetry.
- Realistic global ocean simulations where turbulence dynamics are important.