Coupled ocean modeling with MOM4

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Overview of MOM4

- Code profile
- Algorithms and physics
- Documentation
- Availability
- Outstanding issues

Code profile

- F90 with 2D domain decomposition and `(i,j,k)` index order.

- Parallel infrastructure from FMS (`mpp: MPI/shmem`).

- Namelists, switching in/out of modules, and/or streamlining variations, instead of cpp.

- netCDF format for all I/O, parallelized with `mpp_io`: restarts, diagnostics, initial and boundary conditions, topography, etc.

Algorithms and physics

- non-Boussinesq explicit free surface.

- Generalized horizontal coordinates: Murray (1996) tripolar grid is used, which requires no polar filter.

- neutral physics, KPP mixing, advection schemes, bottom sigma diffusion, partial cells, explicit fresh water, isotropic and anisotropic Smagorinsky friction, modern shortwave penetration, McDougall etal EOS.

- Forward model compatible with adjoint compiler from Giering.

Documentation

- Technical Guide: details of algorithms and diagnostics.

- Fundamentals text: rationale for basics.

- Online User Guide

`http://www.gfdl.gov/~fms`

Availability

Platforms SGI, NEC, IBM, Linux (ifc), Sun.

Support institutionally supported by GFDL with input by researchers internationally. Continues to be developed and upgraded.

Schedule Currently in beta release. Full release planned for summer 2003. Updates on FMS release cycle (roughly 3-6 months).

Outstanding issues

- Eta-coordinate: remove limitation on deviations of top model grid cell with explicit free surface. At present must limit sea ice thickness and tidal fluctuations. An issue for modern climate models with $\sim$10m top cell.

- BBL: non-general formulation with partial cells. BBL thickness limited.

- Advection: Reduce spurious mixing while maintaining enough dissipation.

- Open boundary conditions: collaborative efforts underway to build tools of use for OBCs in ocean and atmospheric models.

- Adaptation to ESMF and PRISM superstructure.

- Use of ESMF community infrastructure.

- Generalized vertical coordinate. Efforts to meld best of Hallberg Isopycnal Model with MOM4 into a MOM5.

Current ocean model configurations

OM2 180x173x50 grid points. KPP, neutral physics, sigma diffusion, tripolar grid, Smagorinsky friction, Quicker advection, shortwave with chlorophyll-a for penetration, non-Boussinesq.

OM3 360x294x50 points.

Features of the FMS coupler

- Encapsulated boundary state and boundary fluxes.
- Single location for initialization and linking of boundary fields.
- Use of field manager to organize operations on individual fields and field bundles.
- Support for serial and concurrent coupling within single executable.

`coupler_main` slow loop

```
do nc = 1, num_cpld_calls
   call generate_sfc_xgrid( Land, Ice )
   call flux_ocean_to_ice( Ocean, Ice, Ocean_ice_flux )
   call update_ice_model_slow_up( Ocean_ice_flux, Ice )
!fast loop
   call update_land_model_slow(Land)
   call flux_land_to_ice( Land, Ice, Land_ice_flux )
   call update_ice_model_slow_dn( Atmos_ice_flux, Land_ice_flux, Ice )
   call flux_ice_to_ocean( Ice, Ice_ocean_flux )
   call update_ocean_model( Ice_ocean_flux, Ocean )
enddo
```

coupler_main fast loop

```
do na = 1, num_atmos_calls
   Time = Time + Time_step_atmos
   call sfc_boundary_layer( Atm, Land, Ice, &
                            Land_ice_atmos_flux )
   call update_atmos_model_down( Land_ice_atmos_flux, Atm )
   call flux_down_from_atmos( Time, Atm, Land, Ice, &
                              Land_ice_atmos_flux, &
                              Atmos_land_flux, Atmos_ice_flux )
   call update_land_model_fast( Atmos_land_flux, Land )
   call update_ice_model_fast( Atmos_ice_flux, Ice )
   call flux_up_to_atmos( Time, Land, Ice, Land_ice_atmos_flux )
   call update_atmos_model_up( Land_ice_atmos_flux, Atm )
enddo
```

Boundary state and boundary flux

- Each model has a **boundary state** and a set of **boundary fluxes** it receives from other models' boundary states.

- The **type** is *defined* by the model.

- The **variable** is *declared* by `coupler_main`.

- The variable, and its connections to another model's fields, is *initialized* by `flux_exchange_init`.

- The data transfer is performed by `flux_exchange`.

MOM4 boundary state and fluxes

```
type ocean_boundary_data_type
   type(domain2D) :: Domain
   real, pointer, dimension(:,:) :: t_surf, s_surf, sea_lev, &
        frazil, u_surf, v_surf
   logical, pointer, dimension(:,:) :: mask
   type (time_type)                 :: Time, Time_step
end type ocean_boundary_data_type

type, public :: ice_ocean_boundary_type
   real, dimension(:,:), pointer :: u_flux, v_flux, t_flux, q_flux
   real, dimension(:,:), pointer :: salt_flux, lw_flux, sw_flux, lprec, fp
   real, dimension(:,:), pointer :: runoff, calving
   real, dimension(:,:), pointer :: p
   real, dimension(:,:,:), pointer :: data
   integer :: xtype             !REGRID, REDIST or DIRECT
end type ice_ocean_boundary_type
```

Flux exchange

- Three types of flux exchange are permitted: `REGRID`, `REDIST` and `DIRECT`.

  REGRID physically distinct grids, requires exchange grid.

  REDIST identical global grid, different domain decomposition.

  DIRECT identical grid and decomposition.

  Current use: `REGRID` between atmos⟺ice, atmos⟺land, land⟺ice, `DIRECT` between ocean⟺ice.

- in `flux_exchange_init`, connections are currently made "by hand". Future use of field manager.

- "Anonymous" operations can use the `data` element of the boundary flux type.

- Could organize boundary types as private to `flux_exchange`.