Technical Report

TR/CMGC/06/36

Oceanic Part of OCC17 Coupled Model : Physical Interface

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This document describes OASIS-V3/NEMO interface of the running Cerfacs coupled model (OCC17): ARPEGE V4.6 atmospheric model, TRIP river flow model and NEMO 2 degrees configuration (nemo_v1 CVS tag), including LIM sea ice routines.

We slightly modified those codes to allow OASIS V3 coupling communication between each component.

I Coupling fields

Models exchange 22 2D fields with a coupling time step of one day. Coupling sequence is the same than IPSLCM4 one (see paragraph 3.2.1 of IPSLCM4 documentation http://dods.ipsl.jussieu.fr/omamce/IPSLCM4/DocIPSLCM4/HTML/).

As IPSLCM4 does, the radiative code sees only one surface (land + ocean + sea-ice) with mean properties. But unlike it, it computes only one net flux for all exchanged fluxes (including turbulent fluxes).

OCC17 coupling insures total water conservation and avoids any kind of heat flux correction.

Coupling fields listed below are described with CF convention standard name (IPCC and CMIP database compliant, if possible), IPCC short name and unit.

I.1 Ocean to Atmosphere

sea_surface_temperature	tos	K
sea_ice_area_fraction	sic	%
surface_albedo	not_IPCC_compliant	%
eastward_sea_water_velocity	uo	m/s
northward_sea_water_velocity	vo	m/s
eastward_sea_ice_velocity	usi	m/s
northward_sea_ice_velocity	vsi	m/s

I.2 Atmosphere to River Flow Model (unseen by ocean)

runoff_flux	mrro	kg/m2/s

I.3 River Flow Model to Ocean

water_flux_into_ocean_from_rivers	not_IPCC_compliant	kg/m2/s

I.4 Atmosphere to Ocean

rainfall_flux	not_IPCC_compliant	kg/m2/s
snowfall_flux	prsn	kg/m2/s
water_evaporation_flux	evspsbl	kg/m2/s
change_over_time_in_surface_snow_flux	not_IPCC_compliant	kg/m2/s
surface_downward_solar_flux	not_IPCC_compliant	W/m2
surface_downward_non_solar_flux	not_IPCC_compliant	W/m2
surface_downward_eastward_stress	tauu (2 interpolations)	N/m2
surface_downward_northward_stress	tauv (2 interpolations)	N/m2
surface_downward_non_solar_flux_derivative	not_IPCC_compliant	W/m2/K
sea_surface_temperature	tos	K
surface_albedo	not_IPCC_compliant	%
wind_speed	not_IPCC_compliant	m/s

Up to date OASIS namcouple : http://www.cerfacs.fr/~maisonna/Dynamite/Files/namcouple

II Modified routines

All modified routines are available in following links:

http://www.cerfacs.fr/~maisonna/Dynamite/NEMO/	calving_issues/ non_solar_flux_interpolation_issues/ general_modifications_for_coupling/ Oasis3_interface/ ice_model_initialization_issues/

Following Wonsun Park and Noël Keenlyside ECHAM5/NEMO developments, 3 new routines have been added to OPA code (get specific modified routines in Oasis3_interface/ subdirectory) and 17 modified (see other subdirectories).

To communicate with OASIS, we modified NEMO using several encapsulated calls to PSMILE library.

cpl_oasis3.F90 mainly contains OASIS initialization routine, with model and fields name declaration, grid characteristics declaration and, possibly, writing on OASIS auxiliary file. The F90 file also includes encapsulated calls to OASIS_send and OASIS_receive and coupling communication ending procedure.

flx_oasis_ice.h90 and tau_oasis_ice.h90 describe respectively fluxes and wind stress computations (in order to determine different fluxes over sea or sea ice surfaces) and OASIS_send routine. flx_oasis_ice.h90 also holds OASIS_receive routine to get atmospheric fields.

III Physical interface

III.1 Ocean to Atmosphere

All fields are updated and sent in flx_oasis_ice.h90. At each model time step, coupling fields are evaluated and sent to OASIS which cumulates them and sends daily mean quantities to atmosphere.

III.1.1 sea_surface_temperature and surface albedo

Mean temperature and mean albedo over sea and sea-ice are sent to atmosphere. Weighting uses sea_ice_area_fraction:

```
! Mean temperature
field_send=tn_ice*(1.0-frld)+(tn(:,:,1)+rt0)*frld
! Mean albedo
field_send=alb_ice*(1.0-frld)+0.065*frld
```

Notice that sea temperature is updated at each ocean model time step, sea-ice fraction and sea-ice temperature at each LIM time step (3 times / day).

LIM model provides ice albedo and sea ice fraction.

III.1.2 sea_ice_area_fraction

Daily mean sea ice fraction is sent to atmosphere. ARPEGE determines if surface is iced (sea_ice_area_fraction > .5) or not (sea_ice_area_fraction <= .5) and calculates fluxes over appropriate surface.

LIM model provides sea ice fraction.

III.1.3 eastward_sea_water_velocity, northward_sea_water_velocity, eastward_sea_ice_velocity and northward_sea_ice_velocity

Eastward and Northward velocities are sent to ARPEGE to correct wind stress calculation. For details see J-J Luo and S.Masson, Reducing Climatology Bias in an Ocean-Atmosphere CGCM with Improved Coupling Physics, J. of Climate, **18**(13), 2344-2360, 2005.

On iced surfaces, we modify stress calculation in ARPEGE, changing the sea water velocity correction by a sea ice velocity correction.

LIM model provides eastward_sea_ice_velocity and northward_sea_ice_velocity.

Notices that OASIS rotates each vector with a new option in SCRIPR interpolation. Auxiliary data needed for U_grid and V_grid rotation are available contacting OASIS support team.

III.2 River Flow Model to Ocean

III.2.1 water_flux_into_ocean_from_rivers

With water flux leaving surface reservoir (ARPEGE coupling field), TRIP collects and routes runoff to the river mouths for all the major rivers.
For details see T. Oki and Y. C. Sud, 1998: Design of Total Runoff Integrating Pathways (TRIP) - A global river channel network. *Earth Interactions*, **2.**

TRIP output field interpolated by OASIS is read by NEMO in flx_oasis_ice.h90 and added to main precipitation minus evaporation quantity in ocesbc.F90.

Due to ARPEGE and OASIS interpolation approximations, runoff values may be negative. A correction in flx_oasis_ice.h90 routines avoids negative values, conserving global water flux.

III.3 Atmosphere to Ocean

III.3.1 snowfall_flux

We separately carry solid and liquid precipitations to allows sea-ice model to compute snow reservoir variations over ice field.

III.3.2 change_over_time_in_surface_snow_flux

This coupling field try to simulate calving, that is to say icebergs discharge.

To avoid snow accumulation over land iced surfaces, OASIS redirects water flux associated with solid precipitations over Greenland and Antarctic. A special interpolation distributes this water flux all over Greenland and Antarctic shores. An extra computation made in LIM code redistributes it, according to sea ice fraction, assuming that icebergs mainly melt on marginal sea ice zones. Routine also computes calving melting energy.

Such operations must be done inside NEMO code because of variations of sea ice extend between two coupling time steps. Calculation takes place in LIM code (limthd.F90) because computing of calving melting energy is done here.

Get specific modified routines in calving_issues/ subdirectory (see chapter II).

III.3.3 rainfall_flux and water_evaporation_flux

In addition to snowfall_flux, flx_oasis_ice.h90 uses both fields to evaluate main precipitation minus evaporation quantity.

```
tprecip_recv(ji,jj) = ( zpliq(ji,jj) + zpsol(ji,jj) - zevwat(ji,jj) ) * tmask(ji,jj,1)
```

III.3.4 surface_downward_solar_flux and surface_albedo

Ocean/sea-ice subsurfaces redistribution of solar flux follows IPSLCM4 scheme (for details see paragraph 3.1.1.0.1. of IPSLCM4 documentation http://dods.ipsl.jussieu.fr/omamce/IPSLCM4/DocIPSLCM4/HTML/). Atmosphere produces a mean quantity (over ocean and sea-ice); redistribution is done in NEMO:

```
! Solar flux over ocean (same value between two coupling step)
qsr_oce(ji,jj) = qsr_recv(ji,jj) * (1-0.065) &
                 / (1-albedo_recv(ji,jj)) * tmask(ji,jj,1)

! Solar flux over sea ice
qsr_ice(ji,jj) = qsr_recv(ji,jj) * (1-alb_ice(ji,jj)) &
                 / (1-albedo_recv(ji,jj)) * tmask(ji,jj,1)
```

OASIS sends mean surface albedo (albedo_recv) at each coupling time step. Sea ice albedo (alb_ice) changes every LIM time step.

III.3.5 surface_downward_non_solar_flux, sea_surface_temperature and surface_downward_non_solar_flux_derivative

Ocean/sea-ice subsurfaces redistribution of non solar flux follows IPSLCM4 scheme (for details, see paragraph 3.1.1.0.2. of IPSLCM4 documentation http://dods.ipsl.jussieu.fr/omamce/IPSLCM4/DocIPSLCM4/HTML/), except that emissivities and heat flux derivatives are supposed to be the same for each subsurface.

OASIS sends mean heat flux derivative (dqns_recv) at each coupling time step.

Mean temperature (temp_recv) is read from OASIS just the first two time steps of experiment. Otherwise, mean temperature sent to atmosphere to compute fluxes is saved in sstday array and, possibly, in OPA restart file.

This field is used 2 coupling time steps after (2 days) in ocean/sea ice subsurfaces redistribution of non solar flux. This technique avoids signal worsening during both ocean_grid -> atmosphere_grid and atmosphere_grid -> ocean_grid interpolations. Notice that atmospheric field is already expanded on the ocean grid using the OASIS SUBGRID interpolation, reducing mismatch between mean flux and subsurface feature (see chapter IV.1.).

```
   ! Non solar flux over ocean
       qnsr_oce(ji,jj) = qnsr_recv(ji,jj) + &
                  dqns_recv(ji,jj) * &
                  ( tn(ji,jj,1) + rt0 - temp_recv(ji,jj) ) &
                  * tmask(ji,jj,1)

   ! Non solar flux over sea ice
       qnsr_ice(ji,jj) = qnsr_recv(ji,jj) + &
                  dqns_recv(ji,jj) * &
                  ( tn_ice(ji,jj) - temp_recv(ji,jj) ) &
                  * tmask(ji,jj,1)
```

Sea ice temperature (tn_ice) changes every LIM time step.

Get specific modified routines in non_solar_flux_interpolation_issues/ subdirectory (see chapter II).

III.3.6 surface_downward_eastward_stress and surface_downward_northward_stress

NEMO receives both eastward and northward components in tau_oasis_ice.h90 module on U and V grids. Wind stress fields are then rotated to model grid using repcmo routine.

III.3.7 wind_speed

TKE Langmuir circulation source term calculation requires 10 meters wind speed module field.

IV Known stability issues

IV.1 Non solar flux interpolation

To interpolate solar and non solar fluxes from t63 atmospheric grid to finer ORCA2 degrees grid, OASIS SUBGRID interpolation is used.

For non solar flux, a first order Taylor expansion of the field on the fine grid relatively to a state variable is performed:

$$\Phi i = F + \frac{\partial F}{\partial T}(Ti - T)$$

where Φi (F) is the heat flux on the fine (coarse) grid, Ti (T) an auxiliary field on the fine (coarse) grid and ∂F/∂T the derivative of the flux versus the auxiliary field on the coarse grid.

Without such interpolation, erroneous values may be calculated during subsurface repartition (flx_oasis3_ice.h90) and instabilities may appear in ice temperature (sist_1d) calculation (limthd_zdf.F90) :

```
!---computation of the derivative of energy balance function
zdfts  =  zksndh(ji)  &      ! contribution of the conductive heat flux
  &     + zrcpdt(ji)  &      ! contribution of hsu * rcp / dt
  &     - dqns_ice_1d(ji)    ! contribution of the total non solar radiation (coupled field)

!---computation of the energy balance function
zfts   = - z1mi0 (ji) * qsr_ice_1d(ji)  & ! net absorbed solar radiation (coupled field)
  &     - qnsr_ice_1d(ji)               & ! total non solar radiation (coupled field)
  &     - zfcsu (ji)                      ! conductive heat flux from the surface

!---computation of surface temperature increment
zdts   = -zfts / zdfts

!---computation of the new surface temperature
sist_1d(ji) = sist_1d(ji) + zdts
```

Unmatchable values of qsr_ice_1d, qnsr_ice_1d and dqns_ice_1d could generate strong values of temperature increment, which induces ice melting, exaggerates ARPEGE fluxes and new overestimation in next temperature increment calculation. Opposite instability could also occur (strong negative values of temperature increment). And both phenomenons could grow simultaneously.

IV.2 Sea ice initial state

Same processes that explained in previous paragraph also takes place in the first time steps of an ocean-at-rest initial state experiment.

In order to avoid induced instabilities, a 10 years long ERA40 forced experiment is performed. From the forced ocean restart, a sable coupled simulation could start.

The forced sea ice restart is slightly modified before coupled experiment launch: we replace forced restart sea ice thicknesses by observed values (get specific modified routines in ice_model_initialization_issues/).

IV.3 Calving fresh water flux

Overestimated fresh water flux added with change_over_time_in_surface_snow_flux coupled field could dramatically modify ocean circulation, particularly in Labrador sea region.
To avoid artificial THC collapse, OASIS-NEMO interfacer will take special care in spatial and temporal repartition of this field.