

Coverage testing for GENIE cupcake

Ian Ross

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The idea here is to collect a set of tests to provide near-complete coverage of the GENIE codebase, in order to help with preventing inadvertent science changes when making wide-ranging code transformations for optimisation. There's a `coverage` script in the main `cgenie` directory that compiles and runs a set of tests with compiler flags suitable for coverage testing, then collects coverage data using the `gcov` program and finally merges the coverage data for the different test runs (you can't use `gcov`'s cumulative coverage collection facility to do this because the executables for different jobs may be different, depending on the model resolution and other preprocessor settings).

The final results are stored in the `gcov-results` directory of the top-level directory in `~/cgenie-jobs` used by the coverage analysis script. There is one coverage file for each Fortran 90 source file in GENIE, with each line annotated with the maximum number of "visits" in any single simulation from the set of test jobs used. Non-executable lines are annotated with a hyphen and executable lines that were never executed are marked with "#####". These latter lines are the most important to consider.

1 Step #1: initial setup and experiments

1.1 Test jobs

The first set of tests includes the following jobs:

ocean-atmos Basic ocean-atmosphere test (the "testebgogs" job) [10 years].

biogem Basic BIOGEM test (the "testbiogem" job) [10 years].

make-restart Restart setup test (the "restartmake" job from the old `fruitcake` test jobs [10 years].

restart-read Restart read test (the "restartread" job from the old `fruitcake` test jobs [10 years].

ocean-geochem-spin-up Includes a large number of ocean tracers, and different use of sediments [100 years].

ocean-geochem-spin-up-2 Follows from above, testing restarts, and uses a fuller range of ROKGEM features [10000 years].

cao-et-al-2009 'Gold standard' modern configuration, including climate components and atmospheric and oceanic biogeochemistry [10 years].

ridgwell-schmidt-2010 Well used paleo configuration, including sediments and basic ROKGEM [10 years].

orbital-variations-abiotic-ocean Very basic climate-only test, but including some additional (orbital) features and a very different continental configuration [100 years].

1.2 Results (subroutine level)

Uncalled subroutines:

atchem/atchem_box.f90 sub_calc_terrCO2exchange, sub_calc_oxidize_CH4,
sub_calc_wetlands_CH4

atchem/cpl_flux_atchem.f90 cpl_flux_lndatm

biogem/biogem_box.f90 sub_calc_bio_uptake_abio, sub_calc_geochem_Fe,
sub_box_oxidize_NH4toNO3, sub_box_oxidize_NH4toNO2, sub_box_oxidize_NO2,
sub_box_reduce_NO2, sub_calc_bio_remin_oxidize_CH4, sub_box_scav_Fe,
sub_calc_scav_Fe, sub_box_scav_H2S, sub_calc_misc_brinerejection,
sub_update_force_flux_atm, sub_update_force_flux_sed, sub_audit_update

biogem/biogem_data_ascii.f90 sub_data_save_global_snap, sub_echo_maxmin

biogem/biogem_data.f90 sub_init_misc2D, sub_init_audit, sub_data_audit_diagnostics,
sub_init_force_solconst

biogem/biogem_data_netCDF.f90 sub_save_netcdf_flux_seaaair, sub_save_netcdf_3d_sig,
sub_save_netcdf_ocn_col_extra, sub_save_netcdf_runtime

common/gem_netcdf.f90 sub_defvar_scalar

common/gem_util.f90 sub_load_data_ijk

embm/embm_diag.f90 diaga, aminmax, diagend_embm, diagfna, diagosc_embm,
read_embm_target_field

embm/embm.f90 field_interp, ocean_alb, rad_out

ents/ents_data.f90 in_ents_ascii, in_ents_netcdf, out_ents

ents/ents_diag.f90 annav_diags, carbt_diags, physt_diags, screen_diags, aminmax1,
slnd_h2o_invent, slnd_c_invent, entsdiagosc

ents/ents.f90 initialise_ents, setup_ents, step_ents, sealevel, carbon, photosynthesis,
veg_resp, leaf_litter, soil_resp

ents/ents_netcdf.f90 netcdf_ents, netcdf_db_ents, netcdf_ts_ents

goldstein/goldstein_data.f90 outm_surf_ocn_sic

goldstein/goldstein_diag.f90 diag, diagend

goldstein/goldstein.f90 coshuffle, ediff, krausturner

goldsteinseaice/gold_seaice_data.f90 diagsic, diagosc_sic

goldsteinseaice/gold_seaice.f90 diagend_seaice, tstipsic

rokgem/rokgem_box.f90 sub_GKWM, sub_GEM_CO2, sum_calcium_flux, sum_calcium_flux_CaSi,
sub_2D_weath

rokgem/rokgem_data.f90 sub_load_rokgem_restart, sub_data_input_3D, sub_load_weath

rokgem/rokgem_data_netCDF.f90 rokgem_netcdf, sub_save_netcdf_2d_rg, sub_save_netcdf

rokgem/rokgem_lib.f90 define_2D_arrays

sedgem/sedgem_box.f90 sub_update_sed_mud, calc_sed_dis_opal

sedgem/sedgem_box_ridgwell2001_sedflx.f90 init_sedflx_Si, runge_kutta_4_opal

sedgem/sedgem_box_ridgwelletal2003_sedflx.f90 init_sedflx_Si, runge_kutta_4_opal

```

sedgem/sedgem_data.f90 sub_load_sed_dis_lookup_CaCO3,sub_load_sed_dis_lookup_opal,
    sub_load_sed_mix_k,sub_sedgem_save_sedcore,sub_data_save_seddiag_2D,
    sub_data_output_years,sub_output_year,sub_output_counters

utils/writenc6.f90 writevar_ld

wrappers/genie_ini_wrappers.f90 initialise_ents_wrapper

wrappers/genie_loop_wrappers.f90 ents_wrapper,cpl_flux_lndatm_wrapper,

    diag_biogem_gem_wrapper

genie_util.f90 die,message

local_netcdf.f90 lookupREAL1dVars,lookupREAL2dVars,lookupREAL3dVars,openNetCDFRead,
    closeNetCDF,handle_err,handle_nc_err

```

1.3 Coverage conditions (subroutine level)

```

atchem/atchem_box.f90

sub_calc_terrCO2exchange atchem/atchem.f90:69

    IF ((par_atm_FterrCO2exchange > const_real_nullsmall) .AND.
        atm_select(ia_pCO2) .AND. atm_select(ia_pCO2_13C)) THEN

sub_calc_oxidize_CH4 atchem/atchem.f90:54

    IF (atm_select(ia_pCH4) .AND. atm_select(ia_pCO2) .AND.
        atm_select(ia_pO2)) THEN

sub_calc_wetlands_CH4 atchem/atchem.f90:59

    IF (atm_select(ia_pCH4) .AND. atm_select(ia_pCO2) .AND.
        atm_select(ia_pO2)) THEN

atchem/cpl_flux_atchem.f90

cpl_flux_lndatm genie.f90:210

    IF (flag_ents) THEN

biogem/biogem_box.f90

sub_calc_bio_uptake_abio biogem/biogem.f90:1171

    if (ctrl_bio_CaCO3precip .AND. sed_select(is_CaCO3)) then

sub_calc_geochem_Fe biogem/biogem.f90:1185

    if (sed_select(is_det) .AND. ocn_select(io_Fe)) then

sub_box_oxidize_NH4toNO3 & sub_box_oxidize_NH4toNO2 biogem/biogem.f90:1140

    if (ocn_select(io_O2) .AND. ocn_select(io_NO3) .AND.
        ocn_select(io_NH4)) then
        if (ocn_select(io_NO2)) then
            call sub_box_oxidize_NH4toNO2(i,j,loc_k1,loc_dtyr)
        else
            call sub_box_oxidize_NH4toNO3(i,j,loc_k1,loc_dtyr)
        end if
    end if
end If

```

```

sub_calc_bio_remin_oxidize_CH4 biogem/biogem.f90:1158

    if (ocn_select(io_O2) .AND. ocn_select(io_CH4)) then

sub_box_scav_Fe biogem/biogem_box.f90:2799

    if (ocn_select(io_Fe)) then
        if (dum_vocn%mk(io2l(io_Fe),kk) > const_real_nullsmall) then

sub_calc_scav_Fe biogem/biogem_box.f90:1420

    if (ocn_select(io_Fe)) then
        DO k=n_k,loc_k_mld,-1
            if (ocn(io_Fe,dum_i,dum_j,k) > const_real_nullsmall) then

sub_box_scav_H2S biogem/biogem_box.f90:2812

    if (ocn_select(io_H2S) .AND. sed_select(is_POM_S)) then
        if (dum_vocn%mk(io2l(io_H2S),kk) > const_real_nullsmall) then

sub_calc_misc_brinerejection biogem/biogem.f90:490

    if (par_misc_brinerejection_frac > const_real_nullsmall) then

sub_update_force_flux_atm biogem/biogem.f90:1573

    IF (force_flux_atm_select(ia)) THEN

sub_update_force_flux_sed biogem/biogem.f90:1590

    IF (force_flux_sed_select(is)) THEN

sub_audit_update biogem/biogem.f90:1923

    IF (ctrl_audit) THEN

biogem/biogem_data_ascii.f90

sub_data_save_global_snap biogem/biogem/f90:2208

    If (ctrl_data_save_GLOBAL .AND. ctrl_data_save_derived)

sub_echo_maxmin biogem/biogem.f90:1923

    IF (ctrl_audit) THEN

biogem/biogem_data.f90

sub_init_misc2D biogem/initialise_biogem.f90:248

    IF (trim(opt_misc_geoeng) /= 'NONE') THEN
        ! initialize geoengineering
        IF (ctrl_debug_lvl2) print*, 'initialize geoengineering'

sub_init_audit biogem/initialise_biogem.f90:227

    IF (ctrl_audit) CALL sub_init_audit()

```

sub_data_audit_diagnostics biogem/end_biogem.f90:14

```
IF (ctrl_audit) THEN
```

sub_init_force_solconst biogem/initialise_biogem.f90:289

```
if (ctrl_force_solconst) call sub_init_force_solconst()
```

biogem/biogem_data_netCDF.f90

sub_save_netcdf_flux_seaair biogem/biogem_data_netCDF.f90:1187

```
IF (ctrl_data_save_slice_fairsea) then
  CALL sub_save_netcdf_flux_seaair()
end if
```

sub_save_netcdf_3d_sig biogem/biogem.f90:2663

```
if (ctrl_data_save_3d_sig) then
  call sub_save_netcdf(loc_yr_save,4)
  CALL sub_save_netcdf_3d_sig()
```

sub_save_netcdf_ocn_col_extra biogem/biogem_data_netCDF.f90:2028

```
IF (ctrl_data_save_derived) THEN
  ! color tracer ratios
  IF (ocn_select(io_colr) .AND. ocn_select(io_colb)) then
    CALL sub_save_netcdf_ocn_col_extra()
  END IF
END IF
```

sub_save_netcdf_runtime biogem/biogem.f90:2652

```
IF (int_t_sig > const_real_nullsmall) then
  IF (ctrl_data_save_sig_ascii) then
    CALL sub_data_save_runtime(loc_yr_save)
  else
    CALL sub_save_netcdf_runtime(loc_yr_save)
  end IF
```

common/gem_netcdf.f90

sub_defvar_scalar Called from sub_save_netcdf_runtime in biogem/biogem_data_netCDF.f90.

common/gem_util.f90

sub_load_data_ijk biogem/biogem_data.f90:672 + others

```
if (ctrl_force_scav_fpart_POC) then
```

embm/embm_diag.f90

All of these just need EMBM diagnostics to be enabled by setting the debug_loop and/or debug_end flags:
diaga, aminmax, diagend_embm, diagfna, diagosc_embm, read_embm_target_field.

embm/embm.f90

field_interp embm/embm.f90:1620

```
IF (flag_ents) THEN
```

ocean_alb,rad_out embm/embm.f90:2258

```
IF (flag_ents) CALL ocean_alb(oscss, osccc, osccday, j, istep)
```

ents/ents_data.f90

Need ENTS to be enabled: **in_ents_ascii, in_ents_netcdf, out_ents**.

ents/ents_diag.f90

Need ENTS to be enabled: **annav_diags, carbt_diags, physt_diags, screen_diags, aminmax1, slnd_h2o_invent, slnd_c_invent, entsdiagosc**.

ents/ents.f90

Need ENTS to be enabled: **initialise_ents, setup_ents, step_ents, sealevel, carbon, photosynthesis, veg_resp, leaf_litter, soil_resp**.

ents/ents_netcdf.f90

Need ENTS to be enabled: **netcdf_ents, netcdf_db_ents, netcdf_ts_ents**.

goldstein/goldstein_diag.f90

These just need GOLDSTEIN diagnostics to be enabled by setting the **debug_loop** and/or **debug_end** flags: **diag, diagend**.

goldstein/goldstein.f90

coshuffle goldstein/goldstein.f90:2477

```
IF (iconv == 1) THEN
```

ediff goldstein/goldstein.f90:1870

```
IF (iediff > 0) CALL ediff
```

krausturner goldstein/goldstein.f90:2130

```
IF (imld == 1) THEN
```

```
...
```

```
DO i = 1, imax
```

```
DO j = 1, jmax
```

```
IF (k1(i,j) <= kmax) THEN
```

```
IF (mldemix(i,j) > 0.0) THEN
```

goldsteinseaice/gold_seaice_data.f90

These just need diagnostics to be enabled by setting the **debug_loop** flag: **diagsic, diagosc_sic**.

goldsteinseaice/gold_seaice.f90

This just needs diagnostics to be enabled by setting the **debug_end** flag: **diagend_seaice**.

tstipsic goldsteinseaice/gold_seaice.f90:538

```
IF (impsic) THEN
```

rokgem/rokgem_box.f90

sub_GKWM rokgem/rokgem.f90:65

```
SELECT case (par_weathopt)
...
case ('GKWM')
```

Also **sub_GEM_CO2**, **sum_calcium_flux_CaSi** and **sub_2D_weath**.

rokgem/rokgem_data.f90

sub_load_rokgem_restart rokgem/initialise_rokgem.f90:72

```
IF (ctrl_continuing.AND.opt_append_data) THEN
```

sub_load_weath rokgem/initialise_rokgem.f90:234

```
IF (par_weathopt.ne.'Global_avg') THEN
```

Also **sub_data_input_3D**.

rokgem/rokgem_data_netCDF.f90

rokgem_netcdf rokgem/rokgem_box.f90:972

```
IF (tstep_count.eq.output_tsteps_2d(output_counter_2d)) THEN
  IF (opt_2d_netcdf_output) THEN
```

Also **sub_save_netcdf_2d_rg** and **sub_save_netcdf**.

rokgem/rokgem_lib.f90

define_2D_arrays rokgem/initialise_rokgem.f90:234

```
IF (par_weathopt.ne.'Global_avg') THEN
```

sedgem/sedgem_box.f90

sub_update_sed_mud sedgem/sedgem.f90:267

```
elseif (sed_mask_muds(i,j)) then
```

calc_sed_dis_opal sedgem/sedgem_box.f90:346

```
select case (par_sed_diagen_opalopt)
case ('ridgwelletal2003lookup')
```

sedgem/sedgem_box_ridgwelletal2003_sedflx.f90

init_sedflx_Si sedgem/sedgem_box.f90:1789

```
select case (par_sed_diagen_opalopt)
case ('ridgwelletal2003explicit')
```

Also **runge_kutta_4_opal**.

sedgem/sedgem_data.f90

sub_load_sed_dis_lookup_CaCO3 sedgem/sedgem_data.f90:672

```
if (par_sed_diagen_CaCO3opt == 'ridgwell2001lookup' .OR.
    par_sed_diagen_CaCO3opt == 'ridgwell2001lookupvec') then
```

```

sub_load_sed_dis_lookup_opal  sedgem/sedgem_data.f90:711

    if (par_sed_diagen_opalopt == 'ridgwelletal2003lookup') then

sub_load_sed_mix_k  sedgem/initialise_sedgem.f90:104

    IF (ctrl_sed_bioturb) THEN
        if (ctrl_sed_bioturb_Archer) then
            ALLOCATE (par_sed_mix_k(0:par_n_sed_mix),STAT=error)
        else

sub_sedgem_save_sedcore  sedgem/end_sedgem.f90:44

    if (ctrl_data_save_ascii) call sub_sedgem_save_sedcore()

sub_data_save_seddiag_2D  sedgem/end_sedgem.f90:47

    if (ctrl_data_save_ascii) call sub_data_save_seddiag_2D(loc_dtyr,dum_sfcsumocn)

sub_data_output_years  sedgem/initialise_sedgem.f90:137

    IF (ctrl_timeseries_output) THEN

sub_output_year  sedgem/sedgem.f90:461

    IF (ctrl_timeseries_output) THEN

        Also sub_output_counters.

wrappers/genie_ini_wrappers.f90
initialise_ents_wrapper  Need to use ENTS!

wrappers/genie_loop_wrappers.f90
Need to use ENTS: ents_wrapper, cpl_flux_lndatm_wrapper.

diag_biogem_gem_wrapper  Needs debug_loop flag to be set.

genie_util.f90
Ignore: die, message.

local_netcdf.f90
lookupREAL1dVars  embm/embm_diag.f90:447

    IF (.NOT. interpolate) THEN
        ...
    ELSE

        Also lookupREAL2dVars, openNetCDFRead and closeNetCDF.

lookupREAL3dVars  goldstein/goldsteain_diag.f90:703

    IF (.NOT. interpolate) THEN
        ...
    ELSE

        Ignore: handle_err, handle_nc_err.

```


1.4 Additional tests (subroutine level)

- ENTS jobs – none of the existing test jobs use ENTS at all. I’ve added a test job derived from an ENTS job in the original `muffin` distribution which should cover at least some of the ENTS code.
- Debug and output – there is quite a bit of diagnostic and data output code that can be exercised by enabling the following options: `debug_loop`, `debug_end`, `ctrl_audit`, `ctrl_data_save_GLOBAL`, `ctrl_data_save_derived`, `ctrl_data_save_slice_fairsea`, `ctrl_data_save_3d_sig`, `opt_2d_netcdf_output`, `ctrl_data_save_ascii`, `ctrl_timeseries_output`. The most efficient way to do this is probably to enable all of these flags for a single test job – I’ve done this for the `ocean-geochem-spin-up-2` job (the `ctrl_timeseries_output` and `ctrl_data_save_GLOBAL` options are excluded from this because they slightly change the output results).
- Atmospheric methane – a suitable job is from Section 5.3 of Andy’s `muffin` examples document: “Modern 36x36x16 configuration + Fe & CH₄ cycles”. The examples document has this running for 10,000 years, but that’s way too long – 100 years should be enough (job name `cover/fe-atmos-ch4`). This job also includes ocean iron dynamics.
- An additional feature is the terrestrial carbon reservoir exchange introduced for doing inversions – I’ve added a `cover/inversion` job to do this.
- I can’t find any example jobs for ocean nitrate and ammonia cycling, although there are some configuration files that look reasonable.
- Ocean methane – Section 6.1 in the examples document is “Eocene 36 × 36 × 16 configuration + CH₄ cycle”, which I’ve set up as `cover/eocene-ch4` and which should exercise some of the ocean methane cycle.
- Sedimentation – I’ve added a job based on Section 2.6.1 in the examples document (part of “Ridgwell and Hargreaves [2007]”) which has some sedimentation forcing (`cover/ridgwell-hargreaves-2007`).

2 Step #2: subroutine gap-filling

2.1 Test jobs

At this point, the coverage test suite includes the following jobs:

- `biogem`
- `cao-et-al-2009`
- `ents`
- `eocene-ch4`
- `fe-atmos-ch4`
- `inversion`
- `make-restart`
- `ocean-atmos`
- `ocean-geochem-spin-up`
- `ocean-geochem-spin-up-2`
- `orbital-variations-abiotic-ocean`
- `restart-read`
- `ridgwell-hargreaves-2007`
- `ridgwell-schmidt-2010`

The next step is to fill in any remaining subroutine-level gaps before looking at smaller-scale results.

2.2 Results (remaining uncalled subroutines)

Uncalled subroutines:

| | |
|--|---------------------|
| biogem/biogem_box.f90 | |
| sub_calc_bio_uptake_abio | NO CONFIGS |
| sub_box_oxidize_NH4toNO3 | SEE #3 BELOW |
| sub_box_oxidize_NH4toNO2 | SEE #3 BELOW |
| sub_box_scav_H2S | NO CONFIGS |
| sub_calc_misc_brinerejection | NO CONFIGS |
| biogem/biogem_data_ascii.f90 | |
| sub_data_save_global_snap | NO CONFIGS |
| biogem/biogem_data.f90 | |
| sub_init_misc2D | NO CONFIGS |
| biogem/biogem_data_netCDF.f90 | |
| sub_save_netcdf_flux_seaair | NO CONFIGS |
| sub_save_netcdf_ocn_col_extra | SEE #4 BELOW |
| sub_save_netcdf_runtime | SEE #5 BELOW |
| common/gem_netcdf.f90 | |
| sub_defvar_scalar | IGNORE |
| common/gem_util.f90 | |
| sub_load_data_ijk | IGNORE |
| embm/embm_diag.f90 | |
| diaga | SEE #6 BELOW |
| aminmax | SEE #6 BELOW |
| diagend_embm | SEE #6 BELOW |
| diagfna | SEE #6 BELOW |
| diagosc_embm | SEE #6 BELOW |
| read_embm_target_field | SEE #6 BELOW |
| ents/ents_data.f90 | |
| in_ents_ascii | IGNORE |
| in_ents_netcdf | IGNORE |
| goldstein/goldstein.f90 | |
| coshuffle | NO CONFIGS |
| ediff | NO CONFIGS |
| krausturner | NO CONFIGS |
| goldsteinseaice/gold_seaice_data.f90 | |
| diagsic | SEE #6 BELOW |
| diagosc_sic | SEE #6 BELOW |
| goldsteinseaice/gold_seaice.f90 | |
| diagend_seaice | SEE #6 BELOW |
| tstipsic | NO CONFIGS |
| rokgem/rokgem_box.f90 | |
| sub_GKWM | NO CONFIGS |
| sub_GEM_CO2 | NO CONFIGS |
| sum_calcium_flux_CaSi | NO CONFIGS |
| sub_2D_weath | NO CONFIGS |
| rokgem/rokgem_data.f90 | |
| sub_load_rokgem_restart | IGNORE |
| sub_data_input_3D | IGNORE |
| sub_load_weath | NO CONFIGS |
| rokgem/rokgem_lib.f90 | |
| define_2D_arrays | NO CONFIGS |
| sedgem/sedgem_box.f90 | |
| sub_update_sed_mud | SEE #7 BELOW |
| calc_sed_dis_opal | SEE #1 BELOW |
| sedgem/sedgem_box_ridgwelletal2003_sedflx.f90 | |
| init_sedflx_Si | SEE #1 BELOW |
| runge_kutta_4_opal | SEE #1 BELOW |

| | |
|---|---------------------|
| <code>sedgem/sedgem_data.f90</code> | |
| <code>sub_load_sed_dis_lookup_opal</code> | SEE #1 BELOW |
| <code>sub_load_sed_mix_k</code> | SEE #2 BELOW |
| <code>sub_data_output_years</code> | IGNORE |
| <code>sub_output_year</code> | IGNORE |
| <code>sub_output_counters</code> | IGNORE |

IDEA #1 [DONE]

Set up a job with base configuration `cgenie.eb_go_gs_ac_bg_sg_rg_gl.p0000e.BASESFeLiCa` and user configuration `EXAMPLE.p0000e.PO4FeSi_S36x36.SPIN`.

BROKEN: the forcings for this aren't available and I've not figured out which forcings I have are compatible. I'm going to ignore this one.

IDEA #2 [DONE]

Need `sg_ctrl_sed_bioturb=.TRUE.` and `sg_ctrl_sed_bioturb_Archer=.FALSE.` (see #7).

IDEA #3 [DONE]

Need selected ocean tracers: O_2 (10), NO_3 (6) and NH_4 (28), then NO_2 (34) selects between `sub_box_oxidize_NH4toNO2` and `sub_box_oxidize_NH4toNO3`.

Added a new job, `nitrogen-no3`, using base configuration `cgenie.eb_go_gs_ac_bg.worjh2.BASESFeN` and user configuration `EXAMPLE.worjh2.PO4FeN.SPIN`. Oxidation to NO_2 seems to require setting some additional parameters, so I'm going to ignore it for now.

IDEA #4 [DONE]

Need a job with colour tracers enabled. I've added a `geoengineering` job with these switched on.

IDEA #5 [DONE]

Need to have `ctrl_data_save_sig_ascii` false for NetCDF output. *I think I'll ignore this one.*

IDEA #6 [DONE]

EMBM and goldSIC have their own `debug_loop` and `debug_end` flags. *These can be switched on for the `ocean-geochem-spin-up-2` job that has all the other debug stuff in it.*

IDEA #7 [DONE]

Need to set `par_sed_Dmax_neritic` to something sensible to trigger mud formation. Quite a few configuration options for this. I've added a `ridgwell-schmidt-2010-mud` that has a depth setting that causes mud formation to be executed. It also has bioturbation set up to cover #2.

2.3 Additional jobs

I've added the following new jobs:

- `geoengineering`
- `nitrogen-no3`
- `ridgwell-schmidt-2010-mud`

and I've modified the `ocean-geochem-spin-up-2` job to include more debugging code.

3 Step #3: small-scale coverage analysis

3.1 Test jobs

At this point, the coverage test suite includes the following jobs:

- biogem
- cao-et-al-2009
- ents
- eocene-ch4
- fe-atmos-ch4
- geoengineering
- inversion
- make-restart
- nitrogen-no3
- ocean-atmos
- ocean-geochem-spin-up
- ocean-geochem-spin-up-2
- orbital-variations-abiotic-ocean
- restart-read
- ridgwell-hargreaves-2007
- ridgwell-schmidt-2010
- ridgwell-schmidt-2010-mud

3.2 Results (remaining uncalled subroutines)

Uncalled subroutines:

| | |
|--|------------|
| biogem/biogem_box.f90 | |
| sub_calc_bio_uptake_abio | NO CONFIGS |
| sub_box_oxidize_NH4toNO2 | NO CONFIGS |
| sub_box_scav_H2S | NO CONFIGS |
| sub_calc_misc_brinerejection | NO CONFIGS |
| biogem/biogem_data_ascii.f90 | |
| sub_data_save_global_snap | NO CONFIGS |
| biogem/biogem_data.f90 | |
| sub_init_misc2D | NO CONFIGS |
| sub_init_force_solconst | NO CONFIGS |
| biogem/biogem_data_netCDF.f90 | |
| sub_save_netcdf_flux_seaair | NO CONFIGS |
| sub_save_netcdf_ocn_col_extra | ??? |
| sub_save_netcdf_runtime | ??? |
| common/gem_netcdf.f90 | |
| sub_defvar_scalar | IGNORE |
| common/gem_util.f90 | |
| sub_load_data_ijk | IGNORE |
| ents/ents_data.f90 | |
| in_ents_ascii | IGNORE |
| in_ents_netcdf | IGNORE |
| goldstein/goldstein.f90 | |
| coshuffle | NO CONFIGS |
| ediff | NO CONFIGS |
| krausturner | NO CONFIGS |
| goldsteinseaice/gold_seaice.f90 | |
| tstipsic | NO CONFIGS |
| rokgem/rokgem_box.f90 | |
| sub_GKWM | NO CONFIGS |
| sub_GEM_CO2 | NO CONFIGS |
| sum_calcium_flux_CaSi | NO CONFIGS |
| sub_2D_weath | NO CONFIGS |

```

rokgem/rokgem_data.f90
sub_load_rokgem_restart  IGNORE
sub_data_input_3D        IGNORE
sub_load_weath           NO CONFIGS
rokgem/rokgem_lib.f90
define_2D_arrays         NO CONFIGS
sedgem/sedgem_box.f90
calc_sed_dis_opal        IGNORE
sedgem/sedgem_box_ridgwelletal2003_sedflx.f90
init_sedflx_Si           IGNORE
runge_kutta_4_opal       IGNORE
sedgem/sedgem_data.f90
sub_load_sed_dis_lookup_opal  IGNORE
sub_data_output_years     IGNORE
sub_output_year           IGNORE
sub_output_counters       IGNORE

```

3.3 Results (unexecuted lines)

“OK” means trivial stuff (where “trivial” means sections of code that, although they might be quite large, are unlikely to be affected by the upcoming optimisation changes); “NC” means there are no configurations available that will trigger this code; numbers refer to the points below.

| | | |
|---------|---|-------------|
| 1/597 | sedgem/sedgem_lib.f90 | OK(1) |
| 1/60 | utils/utill.f90 | OK |
| 2/103 | wrappers/initialise_genie.f90 | OK |
| 2/154 | atchem/atchem_box.f90 | OK(2) |
| 2/19 | utils/open_file_nc.f90 | OK |
| 2/20 | utils/close_file_nc.f90 | OK |
| 2/360 | goldsteinseaice/gold_seaice_netcdf.f90 | OK |
| 2/417 | embm/embm_netcdf.f90 | OK |
| 2/723 | goldstein/goldstein_netcdf.f90 | OK(3) |
| 3/438 | wrappers/genie_global.f90 | OK |
| 5/172 | rokgem/rokgem.f90 | NC |
| 6/159 | atchem/atchem.f90 | OK |
| 6/162 | utils/writenc6.f90 | OK |
| 6/358 | biogem/initialise_biogem.f90 | OK/NC |
| 6/94 | gemlite/gemlite_data.f90 | OK |
| 7/678 | ents/ents_diag.f90 | OK |
| 8/200 | ents/ents_lib.f90 | OK |
| 9/45 | utils/extras.f90 | OK |
| 10/132 | sedgem/end_sedgem.f90 | OK/NC |
| 10/410 | rokgem/rokgem_lib.f90 | NC |
| 10/76 | common/initialise_gem.f90 | OK |
| 13/1047 | sedgem/sedgem_box_archer1991_sedflx.f90 | OK? |
| 16/144 | common/gem_data.f90 | OK |
| 16/299 | embm/embm_data.f90 | OK |
| 16/65 | utils/get1d_data_nc.f90 | OK |
| 20/546 | gemlite/gemlite.f90 | OK(4) |
| 22/77 | utils/get2d_data_nc.f90 | OK |
| 23/451 | goldstein/goldstein_data.f90 | OK(5) |
| 28/103 | wrappers/genie_util.f90 | OK |
| 28/89 | utils/get3d_data_nc.f90 | OK |
| 29/1578 | sedgem/sedgem_data_netCDF.f90 | OK(6) |
| 31/213 | sedgem/initialise_sedgem.f90 | OK(7) |
| 32/119 | sedgem/sedgem_box_benthic.f90 | NC(8) |
| 36/290 | atchem/atchem_data.f90 | OK |
| 37/1652 | biogem/biogem_lib.f90 | OK |
| 37/604 | genie.f90 | NEW JOB (9) |

| | | |
|----------|---|--------------|
| 37/807 | ents/ents.f90 | OK(10) |
| 38/134 | ents/ents_data.f90 | OK |
| 43/279 | rokgem/initialise_rokgem.f90 | OK/NC |
| 50/659 | ents/ents_netcdf.f90 | OK |
| 51/450 | goldsteinseaice/gold_seaice_data.f90 | OK |
| 58/575 | sedgem/sedgem.f90 | OK(11) |
| 59/260 | wrappers/local_netcdf.f90 | OK |
| 87/1156 | common/gem_netcdf.f90 | OK |
| 119/479 | sedgem/sedgem_box_ridgwelletal2003_sedflx.f90 | NC(12) |
| 124/1032 | goldsteinseaice/gold_seaice.f90 | OK/NC |
| 125/1453 | common/gem_carbchem.f90 | NC(13) |
| 189/832 | rokgem/rokgem_data.f90 | OK/NC |
| 219/2700 | biogem/biogem.f90 | NEW JOB (14) |
| 226/799 | embm/embm_diag.f90 | OK |
| 237/1152 | goldstein/goldstein_diag.f90 | OK(15) |
| 237/2475 | biogem/biogem_data_ascii.f90 | OK |
| 255/1931 | common/gem_util.f90 | OK |
| 289/2417 | sedgem/sedgem_data.f90 | OK(15) |
| 305/2072 | sedgem/sedgem_box.f90 | NEW JOB (16) |
| 343/3529 | goldstein/goldstein.f90 | NEW JOB (17) |
| 378/1742 | rokgem/rokgem_box.f90 | OK/NC |
| 443/3598 | embm/embm.f90 | OK |
| 456/3872 | biogem/biogem_box.f90 | OK(18) |
| 584/2999 | biogem/biogem_data_netCDF.f90 | OK |
| 643/3151 | biogem/biogem_data.f90 | OK |

1. Need `ctrl_data_save_wtfrac` to be false.
2. Need `atm_select(ia_pCH4_14C)` and `atm_select(ia_pCO2_14C)` to be set.
3. GOLDSTEIN-specific `debug_loop`.
4. Various tracers: need to have GEMLITE enabled and `ocn_select(io_Ca)` false, `ocn_select(io_SO4)` false, `ocn_select(io_B)` true, `ocn_select(io_F)` true, `ocn_select(io_PO4)` false, `ocn_select(io_SiO2)` true, `ocn_select(io_H2S)` false, `ocn_select(io_NH4)` true. *Probably not worth worrying about...*
5. GOLDSTEIN-specific `debug_init`.
6. Some stuff to do with saving cores, but looks OK.
7. Needs `ctrl_time_series_output`, `ctrl_continuing` and `ctrl_append_data` to be set. *All to do with SEDGEM restarts – OK for now.*
8. Needs `par_sed_diagen_Corgopt` to be set to “arndtetetal2013” – no configs.
9. *Added a new job with `gem_adapt_auto` flag set.*
10. Not sure about `snowswitch` here; also ENTS restarts; plus a couple of other things – should all be OK though.
11. Radioactive tracer; detrital age tracer; foram tracers; debug and time series output – should all be OK.
12. Need `par_sed_diagen_opalopt` set to “ridgwelletal2003explicit” – no configs.
13. Possible values for `par_carbconstset_name`: “DicksonMillero”, “Hansson” “Roy” – no configs.
14. Some stuff to do with forcing of ocean tracers (e.g. Ca and Ca⁴⁴); some stuff to do with sedimentation of opal and POC – *added a calcium-isotopes job.*
15. Some dynamics changes, but all things that would cause breakage elsewhere in executed code if they were wrong.

16. Possible values for `par_sed_diagen_Corgopt`: “simple”, “dunne2007”, “arndtetat2013” – *added a simple-corg-diagen job with “simple setting for this option (only config available).*
17. Hosing experiments: *add hosing job from LABS.*
18. Radioactive tracers; quite a few things to do with tracer indexing; some stuff to do with opal remineralisation – probably all OK though since other things are likely to break along with these.

4 Final job list

Based on the preceding investigations, the full coverage test suite includes the following jobs:

- biogem
- calcium-isotopes
- cao-et-al-2009
- ents
- eocene-ch4
- fe-atmos-ch4
- gem-adapt-auto
- geoengineering
- hosing
- inversion
- make-restart
- nitrogen-no3
- ocean-atmos
- ocean-geochem-spin-up
- ocean-geochem-spin-up-2
- orbital-variations-abiotic-ocean
- restart-read
- ridgwell-hargreaves-2007
- ridgwell-schmidt-2010
- ridgwell-schmidt-2010-mud
- simple-corg-diagen

Some of these are “standard” jobs, while others are “artificial” jobs constructed purely to exercise certain paths through the GENIE code.

Running the full set of coverage tests takes:

| | |
|-----------------------------|----------|
| Test mode (optimised) | 1h 28min |
| Coverage mode (unoptimised) | 3h 00min |

The following modules have changes in the number of unexecuted lines compared to the previous test:

| | |
|----------|---------------------------------|
| 33/604 | genie.f90 |
| 111/1032 | goldsteinseaice/gold_seaice.f90 |
| 122/1435 | common/gem_carbchem.f90 |
| 217/2700 | biogem/biogem.f90 |
| 233/1152 | goldstein/goldstein_diag.f90 |
| 236/2475 | biogem/biogem_data_ascii.f90 |
| 274/2072 | sedgem/sedgem_box.f90 |
| 331/3529 | goldstein/goldstein.f90 |
| 455/3872 | biogem/biogem_box.f90 |
| 582/2999 | biogem/biogem_data_netCDF.f90 |
| 629/3151 | biogem/biogem_data.f90 |