Allow different constant background vertical diffusivity for passive tracers than for active tracers

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Sometimes it is important to allow the background vertical diffusion for passive tracers to be different than for temperature and salinity to get a more realistic simulation. In particular, for simulations with active ocean biogeochemistry a value of the order of $10^{-5} m^2/s$ was found to significantly improve the fidelity of the air-sea exchange of CO_2. However, this value of the background diffusion for active tracers tends to degrade the strength of the overturning circulation in MPAS-Ocean, so in order to account for both of these effects, we will introduce the option for separate values. Research has shown that it is physically justifiable to use different values for active and passive tracers. Note that this implementation will only be applicable to the case of constant background diffusivity, not other options such as Bryan-Lewis. Also note that if more than one passive tracer is enabled, they will all be subject to the choice for this option.

1 Requirements

1.1 Easily choose this option with namelist variables

There should be a logical variable that enables this option, and a real variable with the value of the background diffusivity (m^2/s).

1.2 Solution doesn't change if this option is not chosen

These changes should be added such that the solution is doesn't change if the option to use a different background diffusivity isn't chosen.

1.3 Full passive tracer diffusion coefficient is available for output

We need to define an array that holds the full passive tracer vertical diffusion coefficients so that it is available for output at the user's discretion.

2 Algorithm design

2.1 Calculation of the alternate diffusion coefficients

Since we are restricting the implementation to changes in constant background diffusivity, then new coefficients are easily derived from the active tracer diffusivities:

$\kappa_p = \kappa_a - \kappa_a^{bkgrd} + \kappa_p^{bkgrd}$

where κ_a and κ_p are the full vertical diffusion coefficients for active and passive tracers, respectively, and κ_p^{bkgrd} and κ_a^{bkgrd} are their corresponding constant background values.

3 Implementation

3.1 namelist variables

Create two new namelist variables:

- `config_cvmix_background_diffusion_passive_enable =` *logical*
- `config_cvmix_background_diffusion_passive =` *value*

3.2 Registry variables

Define a new array analogous to `vertDiffTopOfCell`:

```
 <var_struct name="diagnostics" time_levs="1">
--->...
---><var_array name="vertDiffPassiveTopOfCell">
--->...
```

3.3 default values and initialization

The default value set in Registry.xml and namelist_defaults.xml for `config_cvmix_background_diffusion_pass`
should be `.false.`.

The default value set in Registry.xml and namelist_defaults.xml for `config_cvmix_background_diffusion_pass`
should be the same as for the active tracers (`config_cvmix_background_diffusion`),
which is currently $10^{-5} m^2/s$ in Registry.xml and 0.0 in namelist_defaults.xml.

3.4 calculation of passive tracer vertical diffusion coefficients

There are two logical places to assign values to the passive tracer vertical diffusion coefficients: one in `subroutine ocn_vmix_coefs`, the other in `subroutine ocn_vmix_implicit`. In the former, there would need to be quite a few added logical tests. In the latter, there only needs to be one test, so the implementation is much cleaner. Therefore, we will calculate the array in `subroutine ocn_vmix_implicit` right before calling the tridiagonal solve.

4 Testing

We propose testing with 4 month-long simulations using an EC30to60E2r2 G-case including ideal age as a passive tracer.

- Control with the non-modified code
- New feature enabled with `config_cvmix_background_diffusion_passive_enable = .false.`
- New feature enabled with `config_cvmix_background_diffusion_passive_enable = .true.` and `config_cvmix_background_diffusion_passive =` 0.0
- New feature enabled with `config_cvmix_background_diffusion_passive_enable = .true.` and `config_cvmix_background_diffusion_passive =` 10^{-5}

The first 3 simulations should yield identical results, which will be tested using *ncdiff*. The fourth case should have identical T and S compared to the others, but ideal age should be different due to the finite background diffusivity. We will also confirm that the `vertDiffTopOfCell` array is successfully output in the monthly history file.