ACCESS-OM2 water balance

This is an attempt to summarize what ACCESS-OM2 is trying to do and why.

I haven't confirmed in detail that this is what the model actually does, so please comment if any of it looks wrong / doesn't make sense.

When we've got the story straight I'd like to post it on the forum for reference.

Coupling architecture

In the ACCESS-OM2 implementation the atmosphere (YATM) passes prescribed fluxes only to CICE (which is global). YATM has no direct communication to MOM. Instead, CICE transfers atmospheric fluxes to MOM on a pro-rata basis according to the ice coverage fraction (aice) in each cell. See https://github.com/COSIMA/access-om2/wiki/System-description and weighting of ice->ocean atmospheric fluxes by (1 - aice) https://github.com/COSIMA/cice5/blob/master/drivers/auscom/cpl_forcing_handler.F90#L729-L824

namcouple https://github.com/COSIMA/1deg_jra55_iaf/blob/master/namcouple defines the fields passed between model components by the OASIS coupler. There's a line in this file for each field, which defines the field name in the source and destination components.

Incoming freshwater

There are four freshwater fluxes incoming into the combined ocean+ice (MOM+CICE) system (liquid and solid precipitation and runoff in the YATM column below). There are also salt and freshwater fluxes from CICE to MOM (internal to the MOM+CICE system).

Field	YATM field name (outgoing)	CICE field name (incoming)	CICE field name (outgoing)	MOM field name (incoming)
Liquid precip	rain_ai	rain_i	rain_io = (1-aice)*rain_i *	lprec*
Solid precip	snow_ai	snow_i	snow_io = (1-aice)*snow_i *	fprec*
Liquid runoff	runof_ai	runof_i	runof_io = runof_ai + licavf **	runof (river) **
Solid runoff (calving)	licalvf	licalvf_i	licefw_io = 0 **	licefw = 0 **
Ice melt water			melt_io	wfimelt
Ice form water			form_io	wfiform
Salt flux			stflx_io	salt_flx

* MOM receives lprec and fprec, which are the part of rain_ai and snow_ai that doesn't fall on sea ice (i.e. weighted by (1 - aice) as explained above).

** CICE combines solid and liquid runoff, so MOM receives runof = runof_ai + licavf, and licew = 0 https://github.com/COSIMA/cice5/blob/master/drivers/auscom/cpl_forcing_handler.F90#L782-L783, so in the following discussion solid runoff will be omitted.

2. Evaporation

evap_total = evap + evapn (where evap is from MOM and evapn is from CICE) is the only freshwater flux out of the combined ocean+ice system (though both evap and evapn can actually be into the ocean+ice system if condensation/frost takes place; in this case this water is in addition to what comes from YATM).

rain_ai, snow_ai, runof_ai are prescribed, but the components of evap_total are calculated.

MOM evap is calculated (in the CICE code!) by bulk formulas (eqs 4-10 of Large & Yeager 2004 http://dx.doi.org/10.5065/D6KK98Q6) based on MOM SST and YATM prescribed near-surface wind, humidity, air temperature https://github.com/COSIMA/cice5/blob/master/drivers/auscom/surface_flux_mod.F90#L824. Note that this makes no account of the presence of ice, so MOM loses water to evaporation even in places where there is 100% ice cover.

CICE evapn (which includes sublimation) is calculated based on latent heat flux, apparently in this code https://github.com/COSIMA/cice5/blob/master/source/ice_therm_vertical.F90#L1524-L1677.

evap_total simply disappears from the system; it is not coupled to anything. evap_total does not go to the atmosphere (because rain_ai, snow_ai, runof_ai are prescribed, i.e. the atmosphere is not a water vapour reservoir), so there is no feedback from ocean+ice to the atmosphere (the net flux rain_ai + snow_ai + runof_ai + evap_total does not deplete the atmospheric water vapour and so has no effect on the amount of water available for precipitation). As a result, **evap_total generally won't balance rain_ai + snow_ai + runof_ai**, which would lead to a drift in ocean+ice mass (for the Boussinesq ocean, "mass" is actually volume*rho0). In practice this imbalance is O(10%) of rain_ai (i.e. the bulk formula isn't perfect).

3. Enforcing a balanced budget

To prevent drift we need to add a correction flux (let's call it "fudge") so that
fudge + rain_ai + snow_ai + runof_ai + evap + evapn = 0,
i.e. zero net freshwater flux into the ocean+ice system. Since the atmosphere is not a water vapour reservoir, this exact balance would ideally apply at all times (unlike the real world, where the total water in the atmosphere can vary). However, the current implementation does not achieve this, due to (e.g. seasonal) storage and release of fresh water precipitated onto the sea ice, as explained below.

fudge is calculated in MOM (https://github.com/mom-ocean/MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90#L4039-L4078) as fudge = -pme_river_total (https://github.com/mom-ocean/MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90#L4067-L4077) with zero_net_water_coupler = true https://github.com/mom-ocean/MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90#L231-L243.

pme_river_total is the global integral of pme + river - melt
https://github.com/mom-ocean/MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90#L4056-L4062
where
pme = lprec + fprec + wfimelt + wfiform (+ licefw=0) - evap
is the net water flux into MOM, excluding runoff
https://github.com/mom-ocean/MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90#L3630-L3651
and melt is freshwater flux calculated from salt flux using the nominal ice salinity
https://github.com/mom-ocean/MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90#L4014-L4037.

CICE receives its own share of precipitation aice*(rain_ai + snow_ai) and partially-compensating evapn, and exchange with MOM via melt_io + form_io (which arrives in MOM as wfimelt + wfiform). wfimelt + wfiform is the total freshwater flux from sea ice to ocean, so wfimelt + wfiform - melt is the freshwater that originated purely from precipitation (minus evapn) onto ice from YATM, not from melting of ice that had been previously obtained from the ocean (which is an internal exchange between MOM and CICE); in effect, the calculation of melt uses salt to “tag” the portion of water flux that originated from the ocean so it can be subtracted off. If the sea ice water mass was constant in time at each point, pme_river_total would be the total instantaneous water flux from YATM to the MOM+CICE system, i.e. this is the unbalanced total flux we need to remove in some way from the MOM+CICE system. This is not true in practice, because the ice melting in a given location may have precipitated onto the ice months before (and also been advected from a different location), but MOM only finds out about this precipitation when (and where) the ice melts. Nevertheless, this method seems to work well enough in practice to maintain a reasonably constant global- and annual-averaged total ice+ocean freshwater mass.

pme_river_total is a global average, so we need to choose how to distribute it spatially. The code takes the simplest approach of subtracting pme_river_total as a spatially uniform correction to pme everywhere. The lprec diagnostic is also adjusted to make it look like the correction is carried solely in lprec
https://github.com/mom-ocean/MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90#L4067-L4077. pme is adjusted rather than river because it is more spatially uniform
https://github.com/mom-ocean/MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90#L231-L243. lprec is a sensible diagnostic to attribute the adjustment to, as lprec is larger than fprec and runof, and (unlike evap or evapn) adjusting it won't affect the heat balance. Adjusting pme with a spatially uniform offset has disadvantages of adding rain (in the lprec diagnostic) in places where it should be absent (e.g. in regions of 100% ice cover where all precipitation should be intercepted by CICE), and also sometimes producing negative rainfall in some locations. (Perhaps a better method would be to scale lprec by a suitably-chosen spatially-uniform factor, but that's not what was done, I guess for simplicity/efficiency).