P: Identifying and Fixing Water Conservation Errors in the ACME Atmosphere Model

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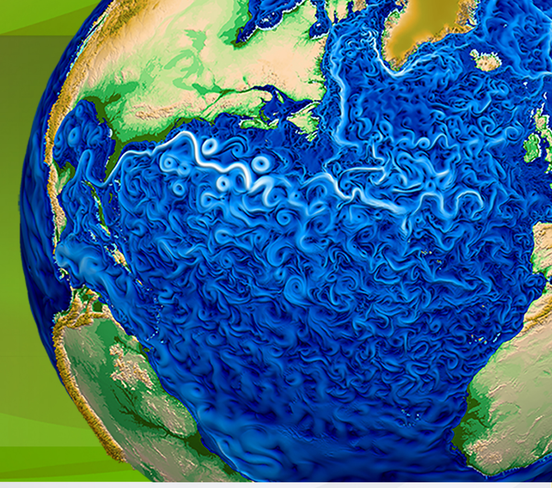


1. Water Conservation Problem in ACME

Water Conservation Error in Alpha6 (similar to Alpha 7)

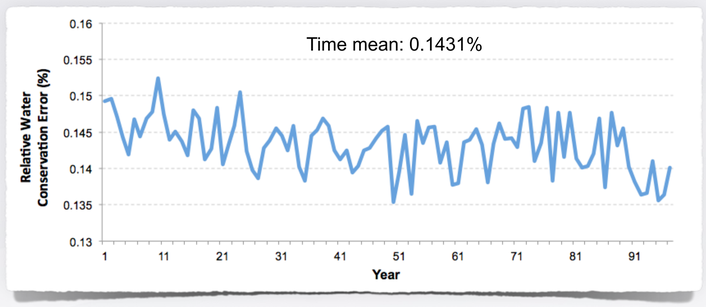


Fig 1. Relative water conservation error (%) in the atmosphere component of ACME alpha-6 ne30L72 coupled model simulation.

In a 100 year simulation, the model artificially gains ~**15 cm** water in terms of global annual mean.

Calculation

Error = **Modeled** – **Expected** … (1)

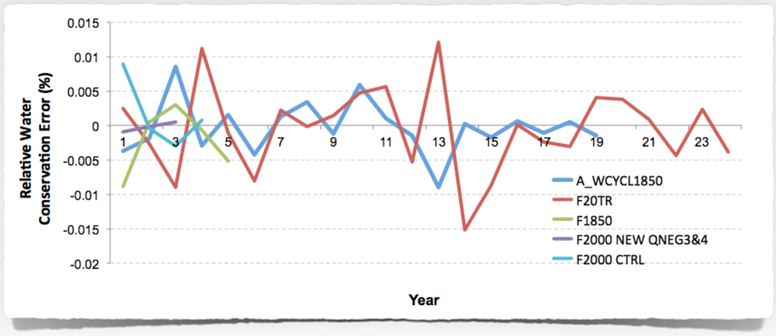
Expected = WQt (t-1) - PRECT*dt + QFLX*dt … (2) **Modeled** = WQt (t) … (3)

Relative Error = **Error** / PRECT*dt … (4)

PRECT*dt is the largest term in equation (1). WQt is the total water storage in the atmosphere (kg m^{-2}), including water vapor, cloud liquid, cloud ice, rain, and snow. PRECT is the total precipitation flux (kg m^{-2} s^{-1}). QFLX is the surface moisture flux (kg m^{-2} s^{-1}).

Improvements in Alpha 8+

Water Conservation Error in New Simulations (Atmosphere Component)



Water is much better conserved in Alpha 8+ simulations (ne30L72) compared to Alpha 6 and 7.

In a 100 year coupled simulation, the artificial gain/ loss of water is estimated to be < **0.02 cm** in terms of global annual mean.

A_WCYCL1850: year 1850 coupled model simulation
F20TR: AMIP type transient simulation
F1850: year 1850 atmosphere-only simulation
F2000: year 2000 atmosphere-only simulation
F2000 NEW QNEG3&4: as F2000, but with the new mass borrower and qqflx fixers to replace QNEG3 & QNEG4 in the original model

2. Sources of Conservation Error

Error Sources Identified from Short Simulations

- **PDC**: Error in the dynamical core that is related to the coupling between the tracer mass tendencies from model physics and from the tracer transport scheme
- **QFLX**: Error associated with inaccurate surface moisture flux used in CLUBB;
- **QNEG4**: Error caused by the QFLX correction (in QNEG4), where QFLX is negative and the available surface moisture can not balance the downward flux;
- **QNEG3**: Error due to clipping of negative tracers after each process (by QNEG3);
- **INPRO**: Internal conservation error in deep convection, CLUBB, and MG2 (including the internal clipping errors).

Table 1. Rank of dominant error sources in the model at different horizontal resolutions.

Rank	ne16L72	ne30L72	ne120L72
1	QFLX	PDC	PDC
2	QNEG4	QFLX	QFLX
3	QNEG3	QNEG4	QNEG4
4	PDC	QNEG3	QNEG3
5	INPRO	INPRO	INPRO

3. Solutions and Future Work

Model Modifications and New Fixers

Alpha 8 default **Optional in Alpha 8** **Not resolved**

- **PDC**: Use a new option for the coupling method between the tracer mass tendencies from model physics and the tracer transport scheme (change se_ftype from 1 to 2)
- **QFLX**: Fixed the bug.
- **QNEG4**: A new qqflx fixer is implemented, which adjusts the water vapor profile very gently, instead of changing the surface moisture flux.
- **QNEG3**: A new mass borrower is implemented. No clipping of negative tracers.
- **INPRO**: Not resolved yet.

Future Work

- More effort to reduce internal water conservation errors in deep convection (Zhang-MacFarlane), vertical diffusion, cloud macrophysics and shallow convection (CLUBB), and cloud microphysics (MG2) parameterizations.
- Better treatment of the coupling between the model physics and dynamics, possibly by reducing the model time step.
- Develop new testing strategies (model and post-processing) to monitor both the water and energy conservation in the model more efficiently.