Comparison of CFC-11 distribution in CCSM, x1-ocean, x3-ocean and 0.4-deg ocean models
Models

- CCSM 3.0
- x1 ocean with normal-year forcing (x1-NY)
- x1 ocean with inter-annually varying forcing (x1-IA)

\{ identical grid \}

- x3 ocean
- 0.4-degree ocean

\{ identical forcing \}
QUESTIONS:

- How different are the CFC distributions in each model?
- Is any one model noticeably ‘better’ than the others?
- How important is forcing versus grid size?
IN GENERAL:

- All models get deep convection wrong in the Southern Ocean: CCSM and x1-NY convect too strongly compared with observations in the Southern Ocean; x3, x1-IA and 0.4-deg models do not convect enough

- All models are too cold relative to observations in the surface Southern Ocean, and so model surface-ocean CFC concentrations are too high (strong temp-dependent solubility)

- In terms of column inventories, the x3 is probably the model that compares best with observations (!) – beware of the danger of just comparing global/column inventories
North Atlantic: a very different picture: WOCE A05 section (Atlantic, 24N)
• x3 and 0.4-deg models are transporting too much CFC into DWBC (even though MOC looks fine) – this is due to too high CFC concentrations in deep convective regions in high-latitude North Atlantic

• CCSM and x1-NY have correct CFC concentration in NADW, but 1) maxima is not on western boundary, and 2) there is one core centered at around 2000m (as opposed to two distinct cores in the observations)
Upper Ocean thermocline ventilation – Pacific P14 line
Conclusions

• Thermocline CFC ventilation looks pretty good in all models compared with observations (as with high latitudes, slightly too much CFC in upper ocean due to temperature bias – models slightly colder than obs)

• Deep convection not great in any of the models – either too much, too little, or the wrong CFC properties being transmitted to depth

• Global/Column inventories can be misleading due to compensating biases (e.g. too much CFC in model upper ocean; too little in deep ocean)
• Higher resolution ocean is not necessarily better!
  (e.g. 0.4-deg ocean generally performs worse than x3 in CFC comparisons; both models have identical forcing)

• Both forcing (same grid, different forcing) and grid (same forcing, different grid) make a huge difference to the results

• CCSM ventilates a little too much in the Southern Ocean; in the North Atlantic, the CFC maxima does not hug the western boundary; no ULSW in CCSM; thermocline ventilation in general good compared with observations.
Global 0.4°
900x600x40 grid points

Global 3°
100x116x25 grid points

similarities

World Ocean Atlas (+Polar Hydrography) PT, S initial conditions
World Ocean Atlas, GLODAP, constant value initial conditions
Daily NCAR/NCEP, monthly ISCCP, Xie-Aarkin/MSU precip, runoff
278 ppm atmospheric CO₂
Mahowald dust deposition; Bottom iron flux (depth<1000m)
30 day restoring of SST, SSS under “ice”; 1 year for open ocean SSS
3rd order upwind advection (not positive definite)
KPP mixed layer; Variable thickness surface layer; UNESCO EOS

differences

North grid pole displaced into Hudson Bay
Smith-Sandwell, IBCAO,BEDMAP bathymetry
Biharmonic horizontal tracer diffusion
Biharmonic horizontal momentum diffusion
30 minute timestep

North grid pole displaced into Greenland
ETOPO5 bathymetry
GM eddy diffusion and transport
Anisotropic laplacian viscosity
1 hour timestep