Key issues arising in CM4 development
At GFDL

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Recent history of GFDL climate models

**CMIP3**
- Previous generation
- circa 2004-2006

**CMIP5**
- Current generation
- circa 2009-2012

**CM2**
- ESM2-M, ESM2-G
  - carbon cycle

**CM2.5, CM2.6**
- hi-res coupled models

**CM2.1 + DA**
- seasonal-decadal forecasts

**CM3**
- chemistry
- aerosols
- indirect effects

**HiRAM**
- hi-res atmosphere
- tropical storms

**CM4, ESM4**
- Next generation
  - circa 2016
Ocean model (MOM6): Adcroft, Hallberg

$\frac{1}{4}$ degree model is primary target

1 degree model also under development

C-grid

Generalized vertical coordinate (just beginning to explore)

Backscatter to energize poorly resolved mesoscale eddies
(see Jansen poster)

New mixed layer scheme
ePBL: new mixed layer model
Bob Hallberg, in prep.

Constrains boundary layer mixing using energetics.

Captures the physical content of bulk mixed layer ideas, but works robustly for any coordinate system.

Very stable numerically in tests with proto-CM4 and less resolution dependent than KPP.

Readily extended to include other physical processes and has well defined and easily understood tunable parameters
Magnitude of Seasonal Cycle: Range of Monthly Mean Sea Surface Temperatures in CM4 Prototypes

ePBL

KPP

Observed WOA05
AM4 Atmosphere

FV3 dynamical core
- 50km or 100km horizontal resolution
- 32 or 48 vertical levels
- “light” aerosols/chemistry or ”full” aerosols/chemistry

2 likely options (comparable computationally)
- A) 100km / 48 levels / full aerosols/chemistry
- B) 50 km / 32 levels / light aerosols/chemistry
We would like to unify boundary layer, shallow convection, deep convection, but have not succeeded

**AM2**: boundary layer, [shallow convection, deep convection]

**HiRAM**: boundary layer, [shallow convection, deep convection]

**CLUBB**: [boundary layer, shallow convection], deep convection (Golaz, Guo)

**AM3**: boundary layer, shallow convection, deep convection

**AM4**: boundary layer, shallow convection, deep convection
A new double-plume convection (DPC) scheme motivated by recent literature on convective parameterization and MJO simulation (M. Zhao)

Base on the single bulk plume model used in HIRAM (Bretherton et. al 2004):

- additional (deep) plume with entrainment dependent on ambient RH for representing deep/organized convection, using quasi-equilibrium cloud work function for closure
- cold-pool driven convective gustiness via precipitation re-evaporation

Calibrating using
- mean precip,
- response of precip, LW and SW CRE to ENSO,
- MJO simulation,
- global TC statistics,
- equatorial Pacific cold tongue and dry bias
Manipulating Cloud Feedback (and climate sensitivity) through convective microphysics

Cess sensitivity

M. Zhao, J. Clim 2014

Change in cloud feedback

Change in convective condensation efficiency
(condensate passed to large-scale from convection per unit precip)
Manipulating Cloud Feedback (and climate sensitivity) through **convective microphysics**

Change in **condensation efficiency**
(condensate passed to large-scale from convection per unit precip)

M. Zhao et al in review

- Only changing convective microphysics
In tropical atmosphere, we would like to simultaneously have good simulations of MJO, TC genesis, convectively-coupled waves. Does quality of simulations of these phenomena vary coherently when manipulating convection scheme, etc?

Not in our experience!

We have models with
good TCs, poor MJO, poor CCWs
poor TCs, good MJO, poor CCWs
good TCs, good MJO, poor CCWs <= where we are now
Madden-Julian Oscillation (MJO)
OLR Lag correlation, Winter (Nov-Apr)

Observations

HiRAM-like convection

AM3-like convection

CM4 prototype

Zhao et al. (in prep.)
Tropical cyclones in CM4 (coupled) prototype
Effect of change in convection scheme on TCs in HiRAM

Inhibiting parameterized convection =>

Zhao, Held, Lin JAS 2012
Sensitivity of global mean frequency to "divergence damping" in dynamical core

Zhao, Held, Lin JAS 2012
ENSO quality in CM4 prototype

- surface temperature (°C)
  - all months, regressed onto NINO3 SSTA

(a) ERSST.v3b (1949–2012)

(b) CM4_c96L32_am4g5r2_2000_sis2_low_mixing3b (0001–0100)

(c) Difference (b)–(a)

corr(a,b) = 0.95  RMSD(a,b) = 0.097

NINO3.4 SST spectra

(a) NOAA ER.v2 obs (1957–2002)
(b) CM4_c96L32_am4g5r2_2000_sis2_low_mixing3b (0001–0100)

fields interpolated to (a) grid

corr(a,b) = 0.94  RMSD(a,b) = 0.0732
New boundary layer (based on Mellor-Yamada prognostic TKE (C.Golaz)

SW cloud radiative effect bias
Atmospheric simulations with fixed SST

AM4 prototype

bias = 0.60; corr = 0.91; rms = 9.0

AM4 Prototype with alternate PBL

bias = 0.31; corr = 0.91; rms = 8.9
Comparison with other CMIP5 models

<table>
<thead>
<tr>
<th>Indicator</th>
<th>500 hPa geopotential height</th>
<th>200 hPa v wind</th>
<th>850 hPa v wind</th>
<th>200 hPa u wind</th>
<th>850 hPa u wind</th>
<th>TOA SW up</th>
<th>OLR</th>
<th>Surface pressure</th>
<th>Surface air temperature</th>
<th>Precipitation</th>
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<tbody>
<tr>
<td>Better</td>
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**Caveat:** CM4 results from present-day control simulation. CMIP5 models from historical simulations.

**PCMDI Metrics**

Values are RMS error normalized by the ensemble median (Gleckler et al. 2008)

**Credit:**
Erik Mason
John Krasting
Peter Gleckler

**CM4 prototype**

**CMIP5 GFDL**
Implications for new CPTs?