Key issues arising in CM4 development At GFDL

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plus the entire
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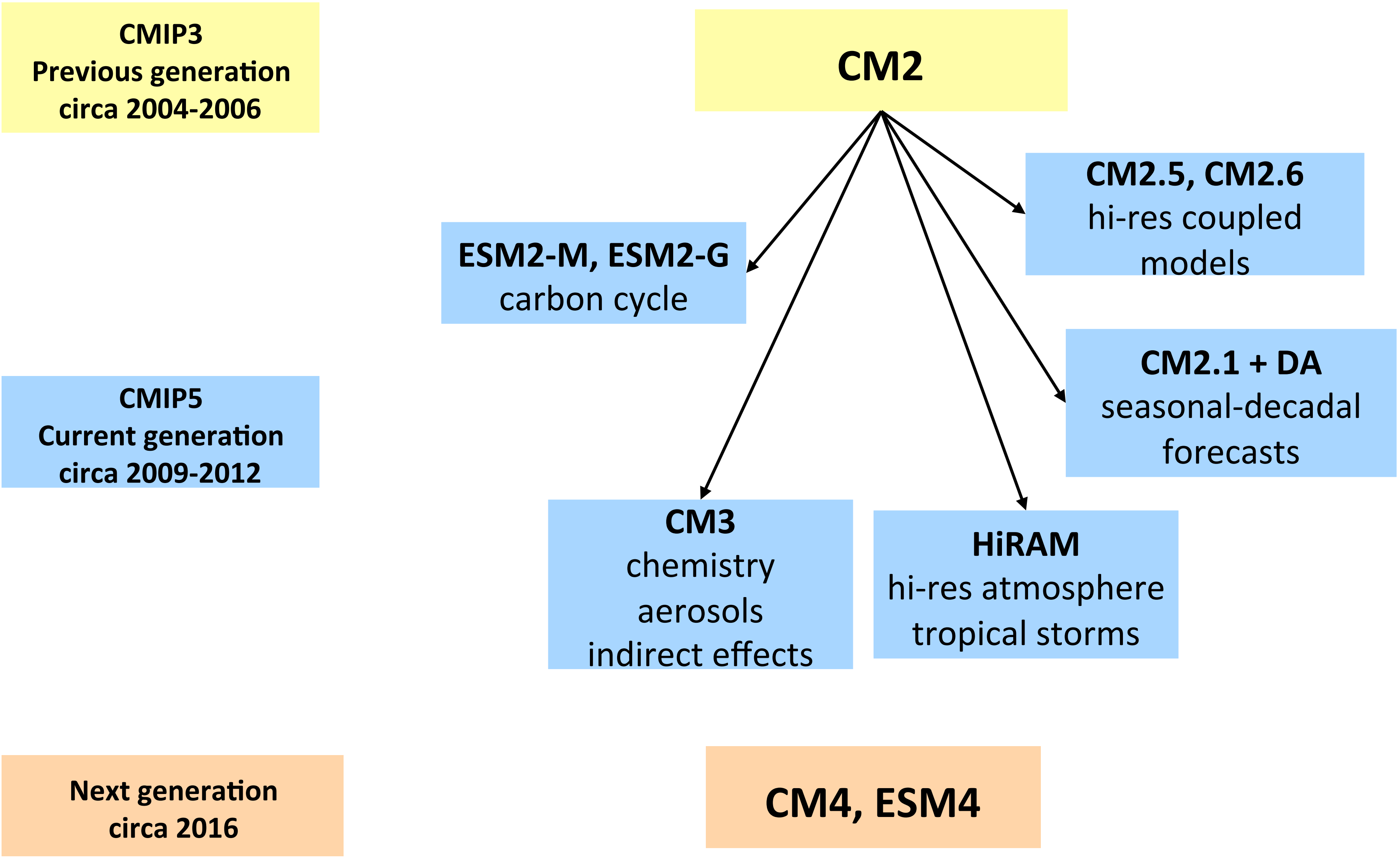
Recent history of GFDL climate models



Ocean model (MOM6): Adcroft, Hallberg

¼ degree model is primary target

1 degree model also under develpment

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.

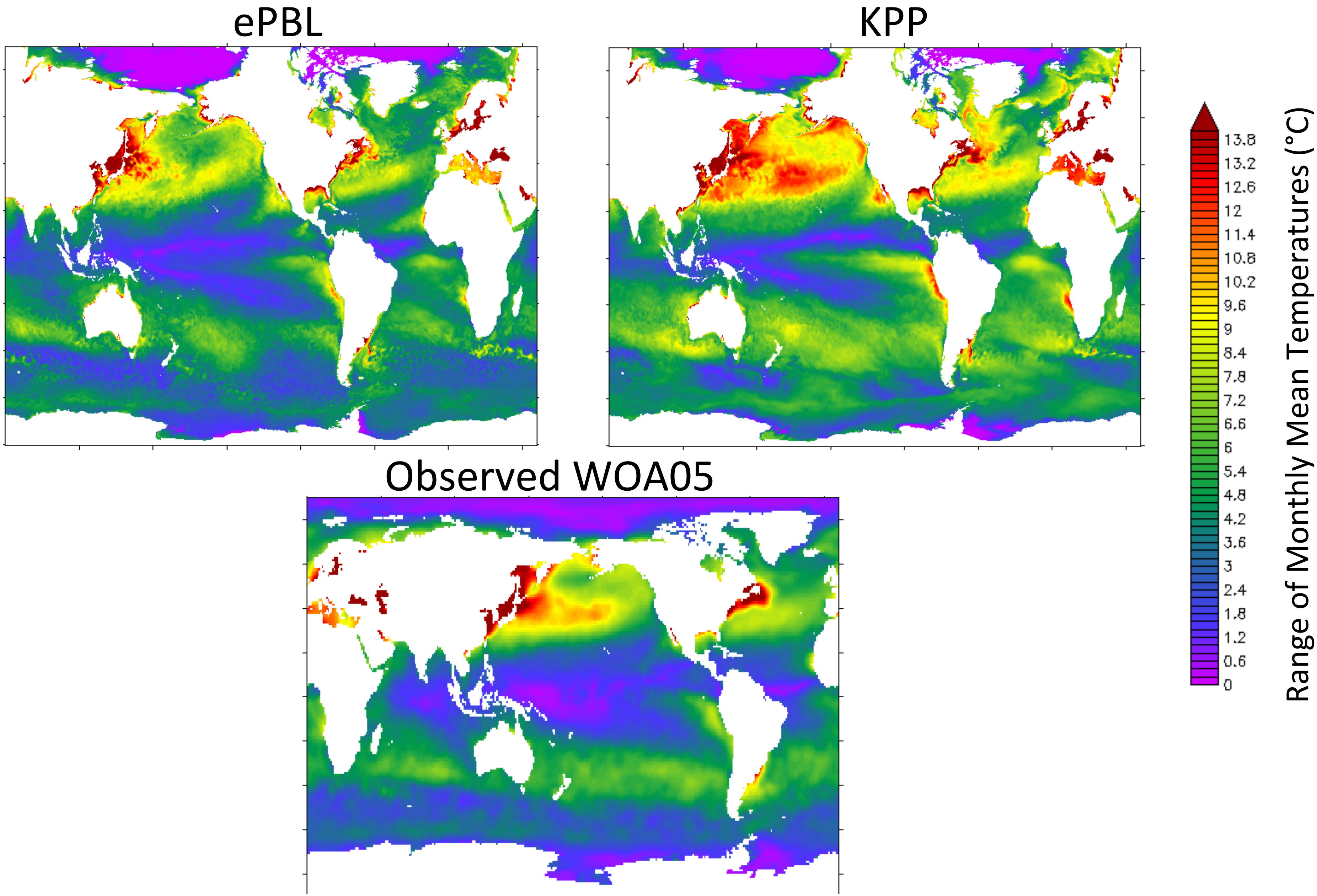
Constrains boundary layer mixing using energetics.

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



AM4 Atmosphere

FV3 dynamical core

50km or **100km** horiizontal 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 parameterizaton 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

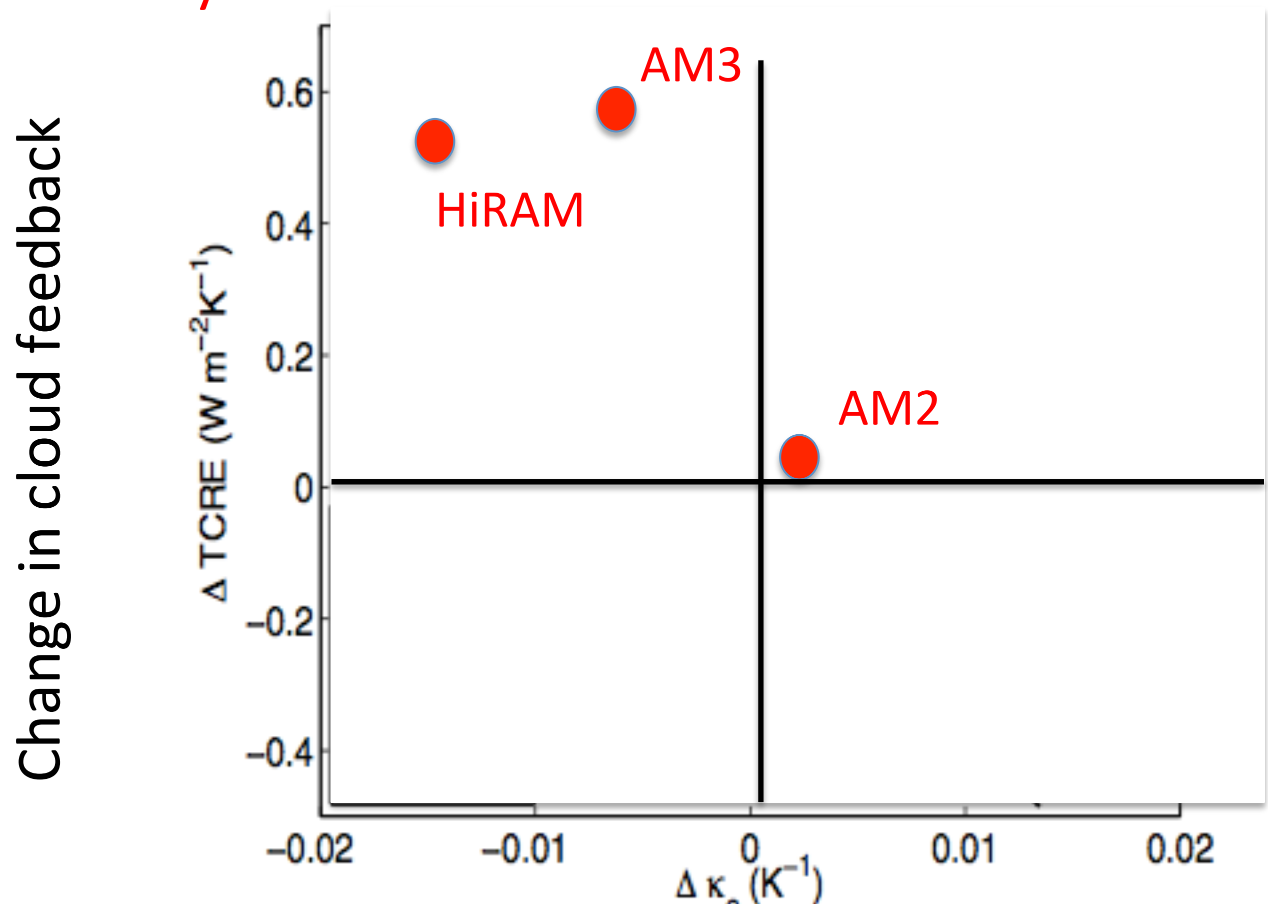
Calibrating using

- 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



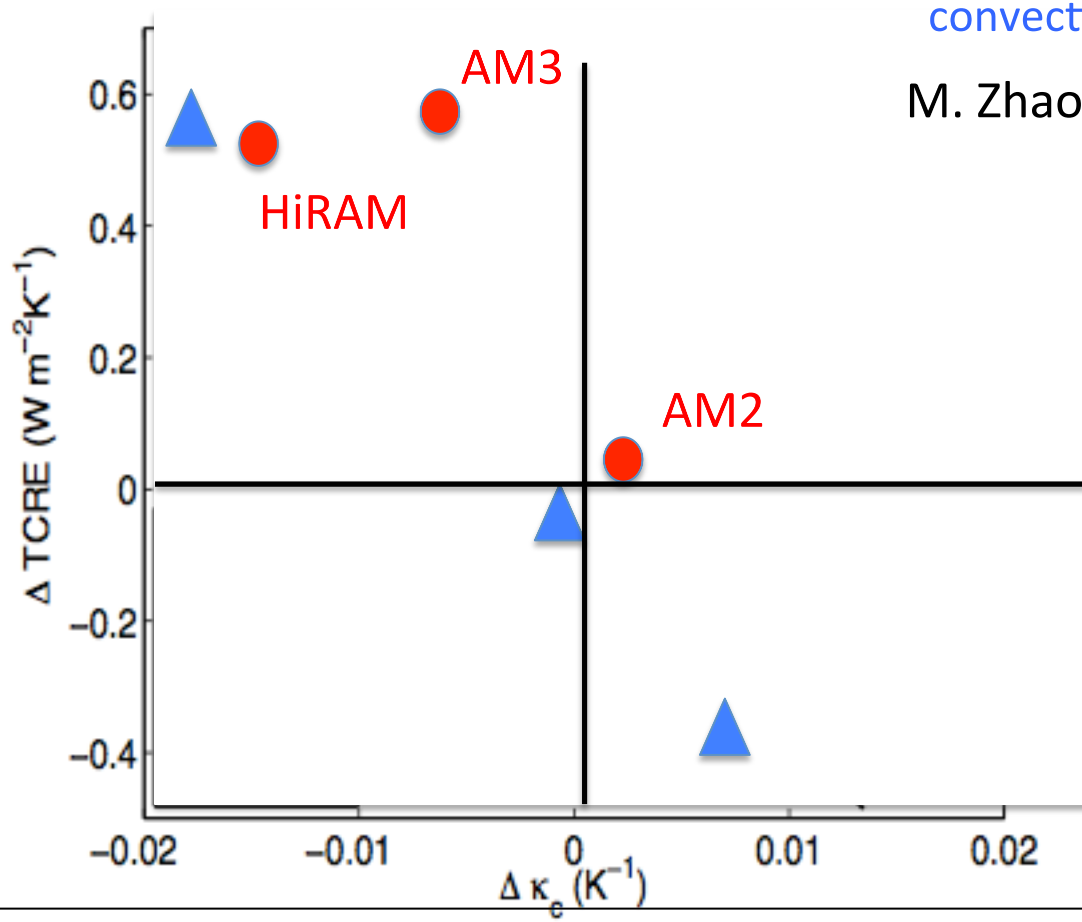
Change in convective condensation efficiency
(condensate passed to large-scale from convection per unit precip)

Manipulating Cloud Feedback (and climate sensitivity) through convective microphysics

▲ = only changing convective microphysics

M. Zhao et al in review

Change in cloud feedback



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

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!

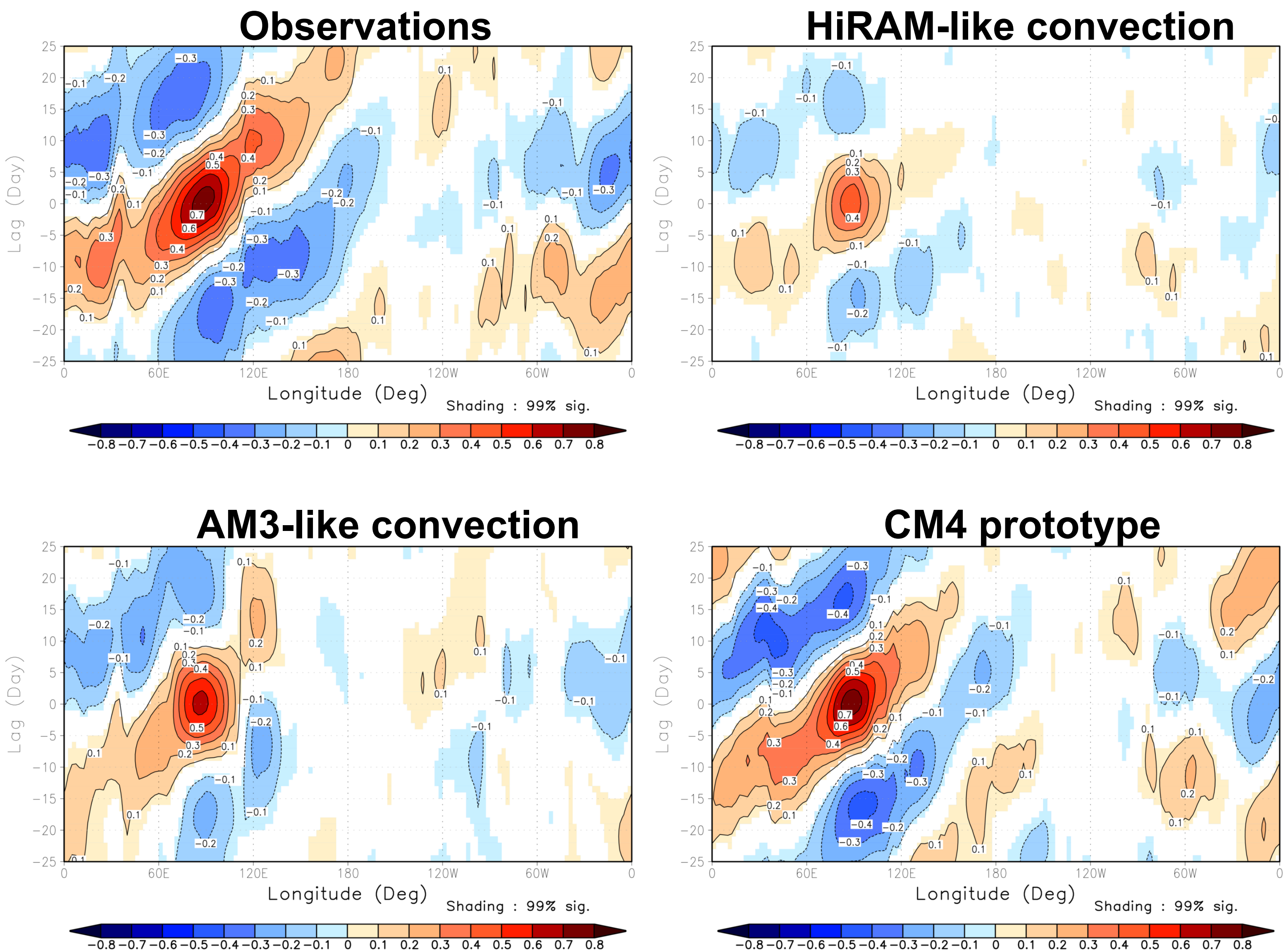
We have models with

good TCs, poor MJO, poor CCWs

poor TCs, good MJO, poor CCWs

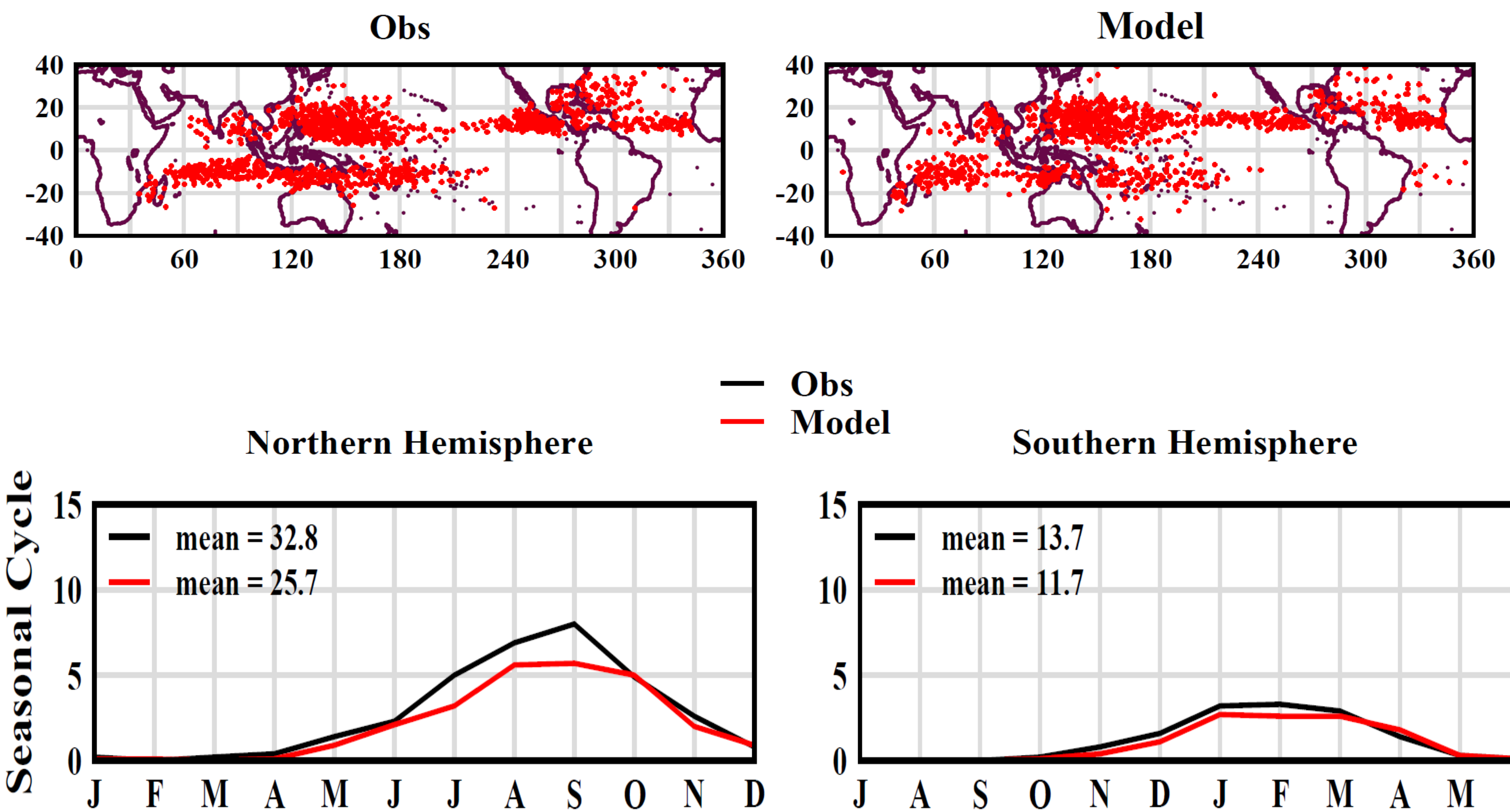
good TCs, good MJO, poor CCWs <= where we are now

Madden-Julian Oscillation (MJO)
OLR Lag correlation, Winter (Nov-Apr)



Zhao et al. (in prep.)

Tropical cyclones in CM4 (coupled) prototype

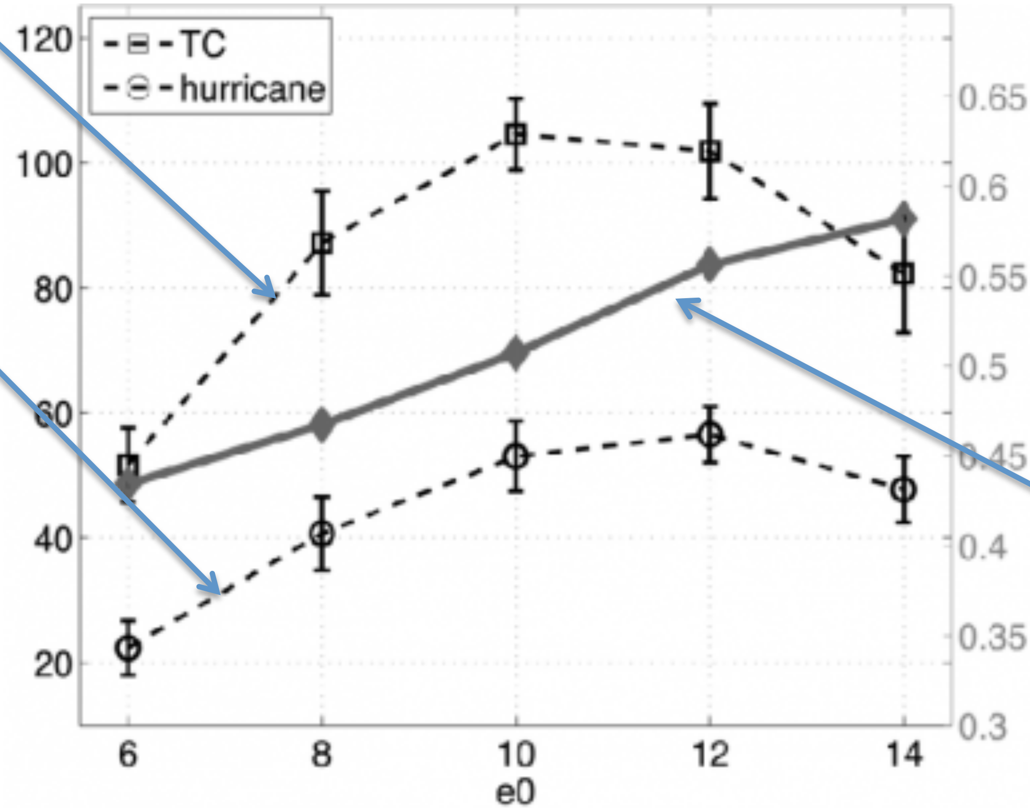


Effect of change in convection scheme on TCs in HiRAM

TCs

Zhao, Held, Lin JAS 2012

Hurricanes

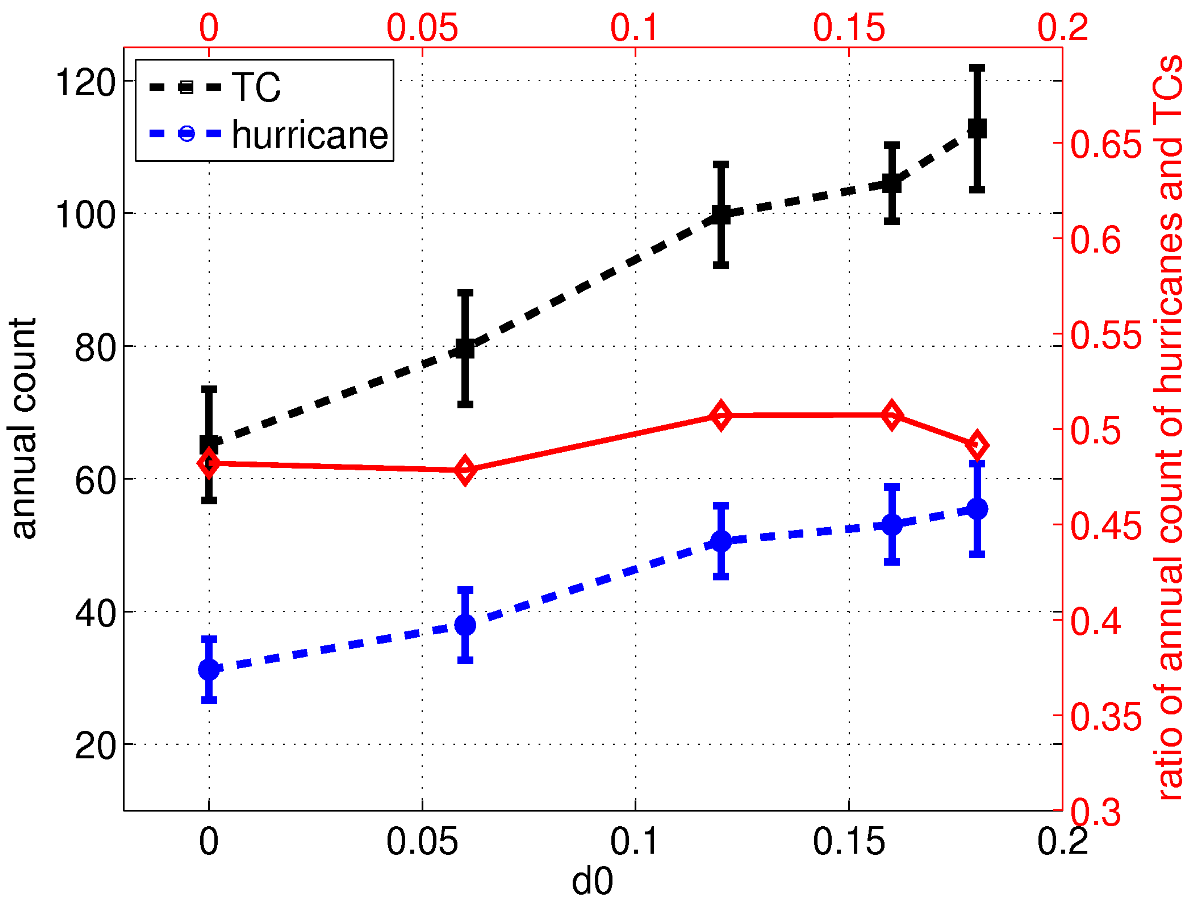


Hurricanes/TCs

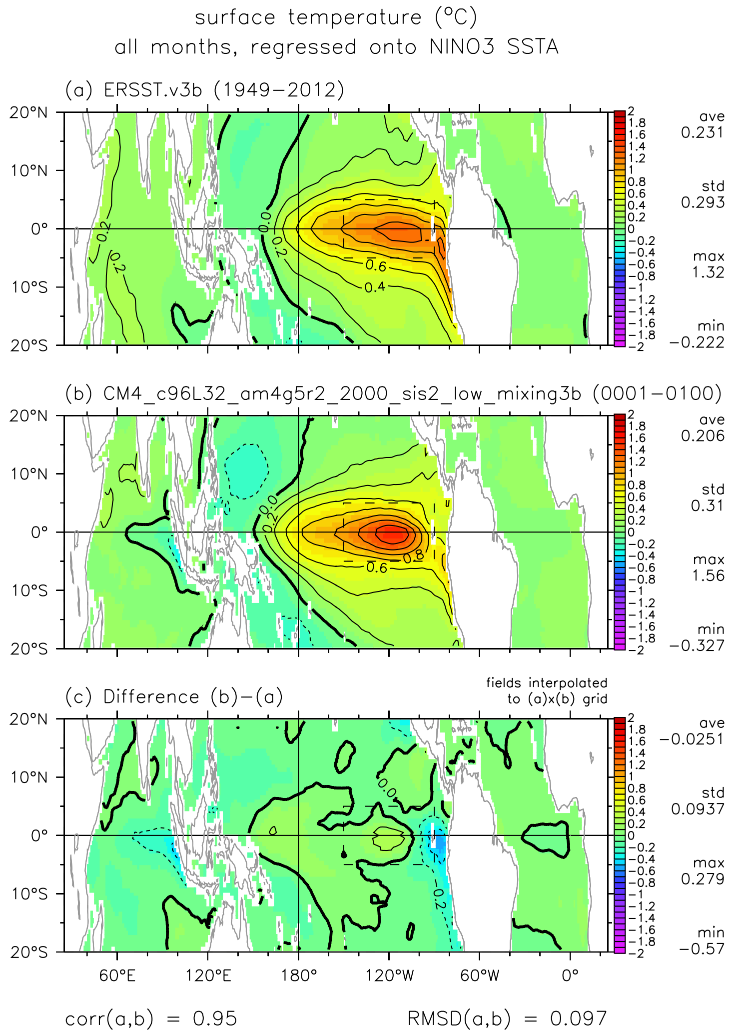
Inhibiting parameterized convection =>

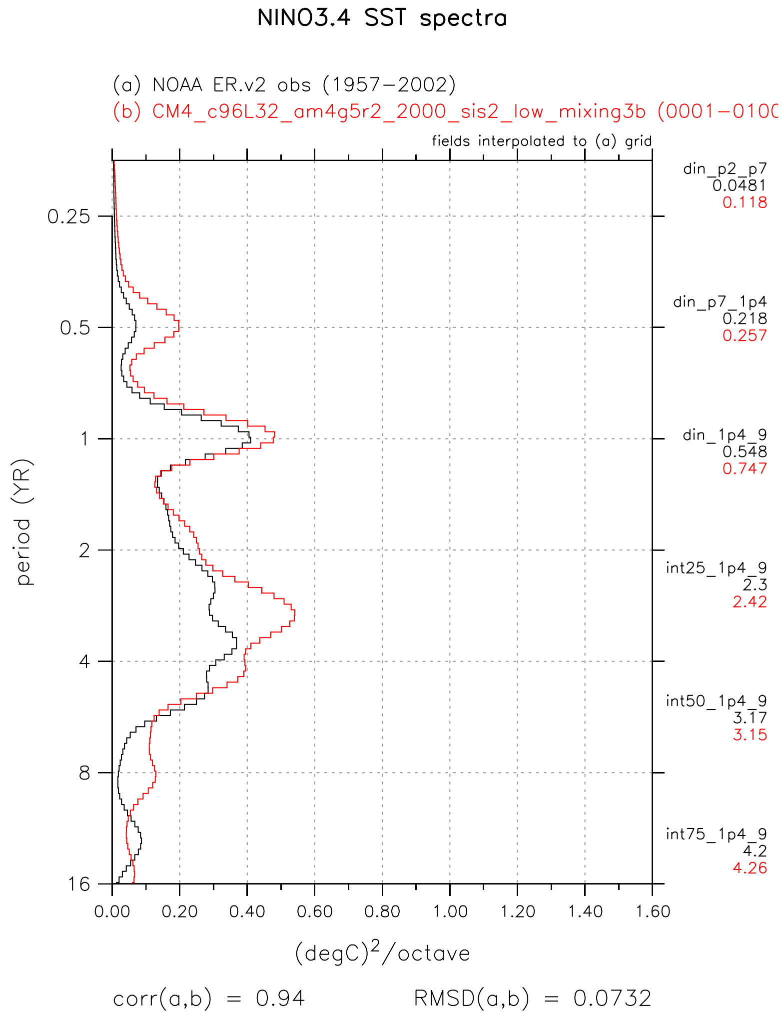
Sensitivity of global mean frequency to "divergence damping" in dynamical core

Zhao, Held, Lin JAS 2012



ENSO quality in CM4 prototype

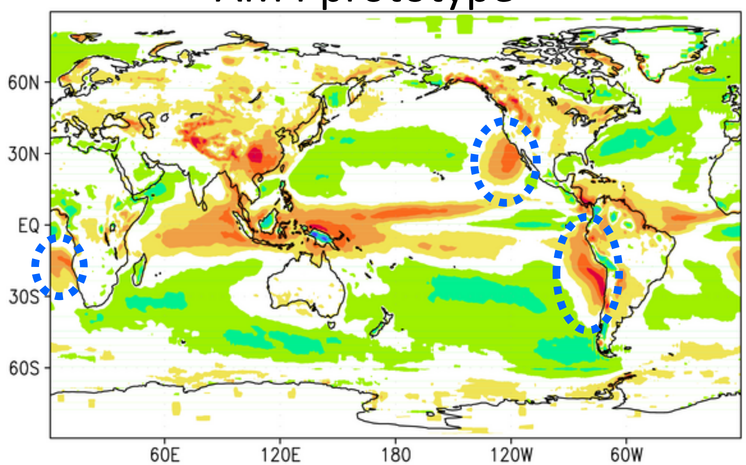




New boundary layer (based on Mellor-Yamada prognostic TKE (C.Golaz)

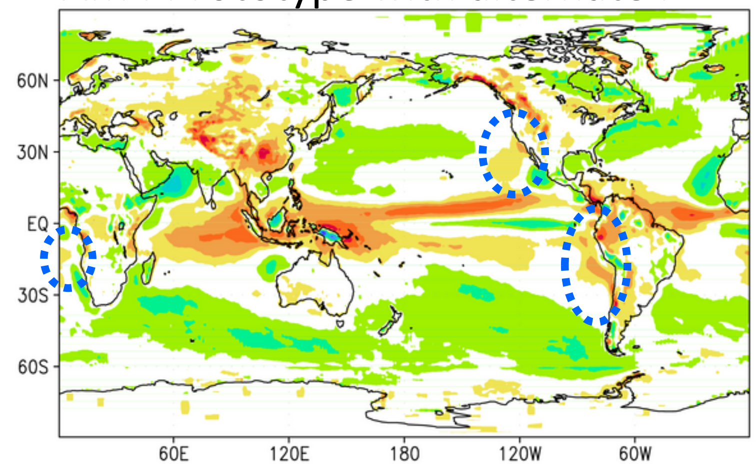
SW cloud radiative effect bias
Atmospheric simulations with fixed SST

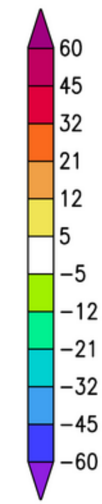
AM4 prototype



bias = 0.60; corr = 0.91; rms = 9.0

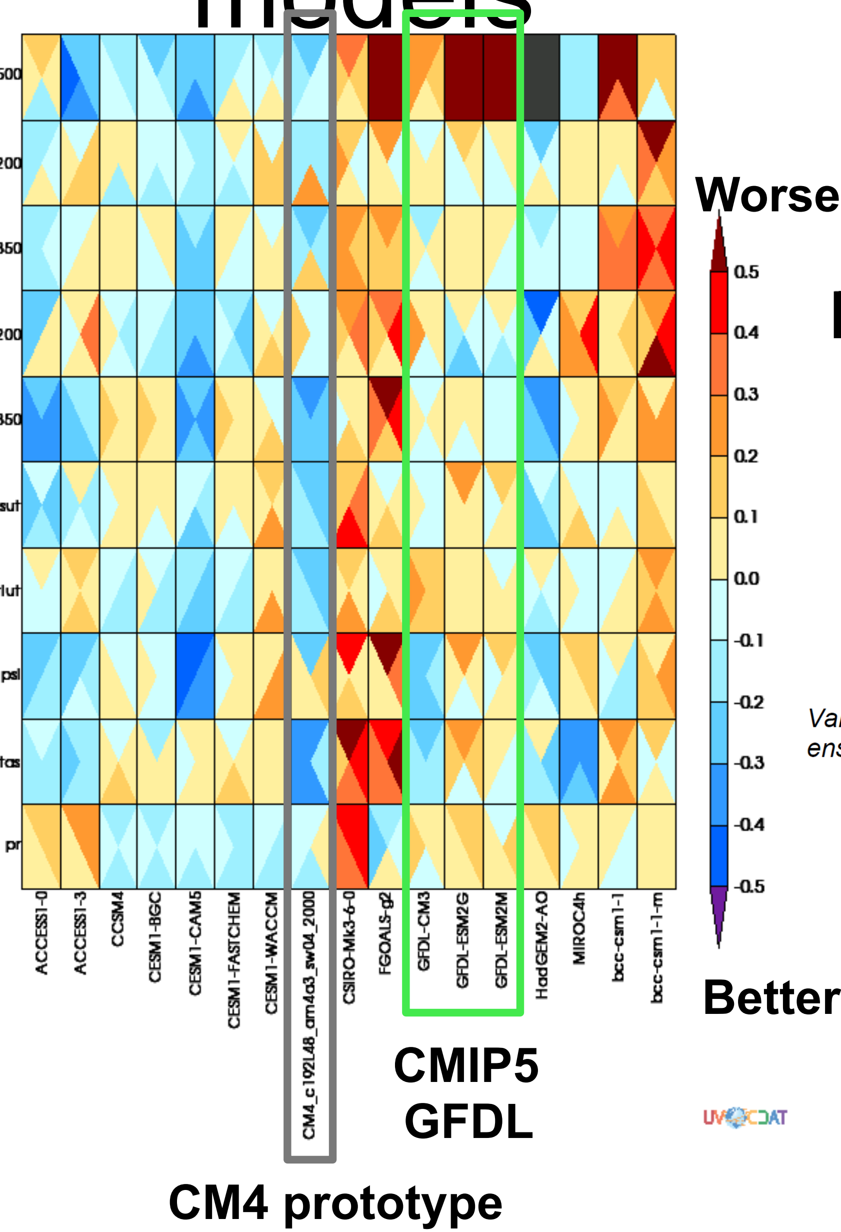
AM4 Prototype with alternate PBL



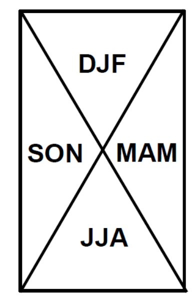


bias = 0.31; corr = 0.91; rms = 8.9

Comparison with other CMIP5 models



PCMDI Metrics



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

Caveat: CM4 results from present-day control simulation. CMIP5 models from historical simulations.

Credit:
Erik Mason
John Krasting
Peter Gleckler

Implications for new CPTs?