NCEP/GFDL/UW/JPL Cloud and Boundary Layer CPT

NCEP: Jongil Han (PI), Ruiyu Sun

GFDL: Chris Golaz (PI), Ming Zhao

JPL: Joao Teixeira (PI), Marcin Witek

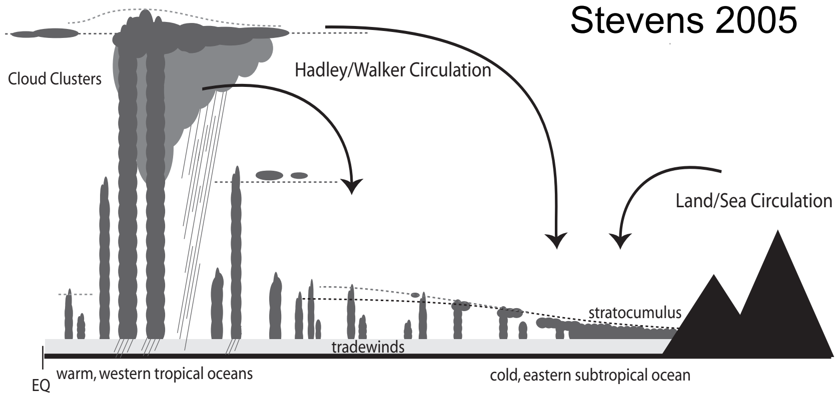
U. Washington: Chris Bretherton (Lead PI),
Chris Jones, Peter Blossey

MAPP
Modeling, Analysis, Predictions, and Projections

Context: NOAA Sc-Cu Transition CPT (2010-2013)

Goal: Improve the representation of the cloudy boundary layer in NCEP GFS and NCAR CAM5 with a focus on the subtropical stratocumulus to cumulus (Sc-Cu) transition

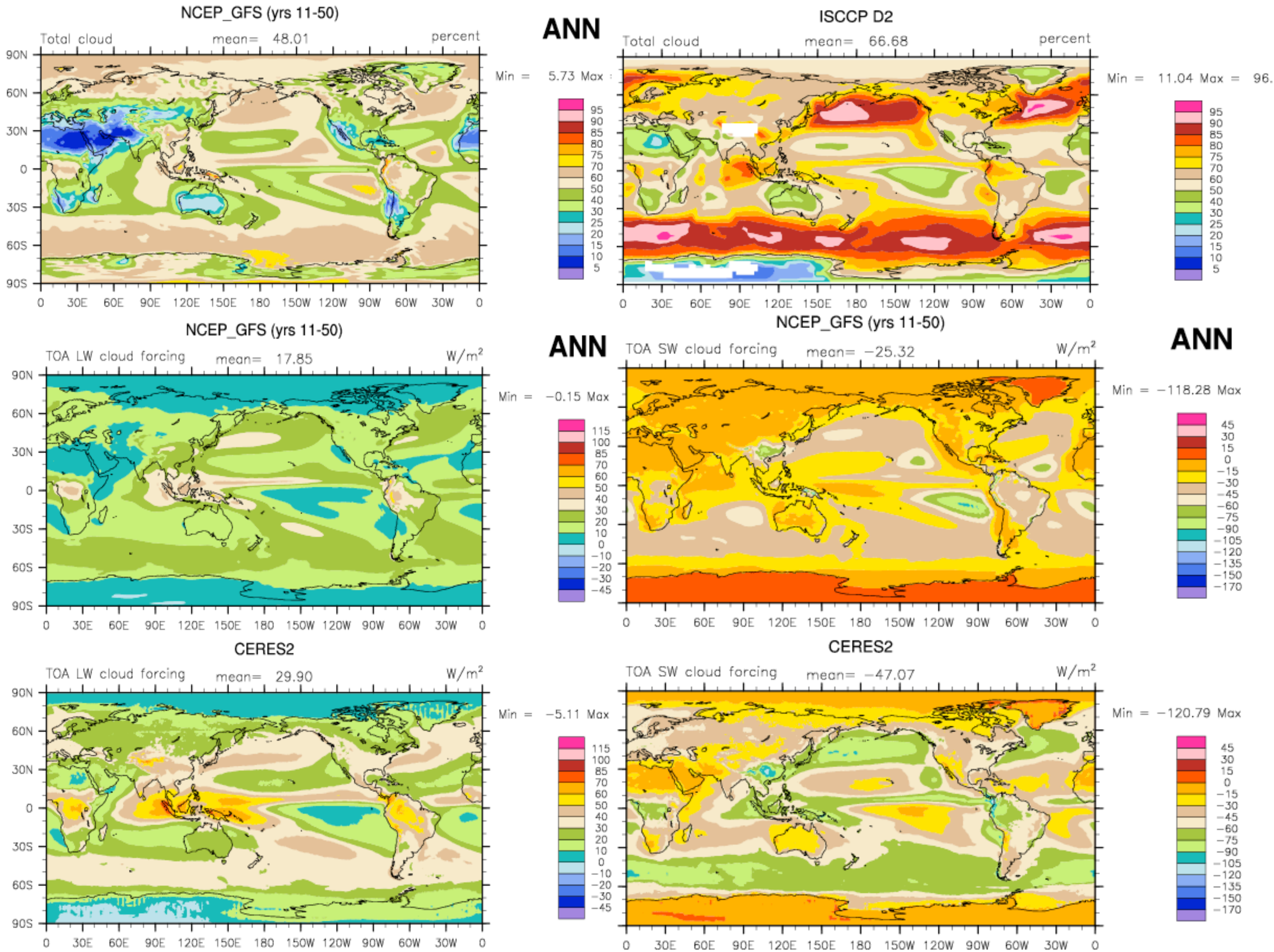
NCEP H. Pan (PI), J. Han, R. Sun
NCAR S. Park (PI), C. Hannay
JPL J. Teixeira (CPT lead PI), M. Witek
UW C. Bretherton (PI), J. Fletcher, P. Blossey
UCLA R. Mechoso (PI), H. Xiao
LLNL S. Klein (PI), P. Caldwell



Stevens 2005

Key GFS diagnostic findings (Xiao et al. 2014 *Clim. Dyn.*):

1. GFS and CFSv2 have too little cloud almost everywhere
2. GFS loses 5-10 W m^{-2} from neglect of TKE dissipation heating
3. GFS subtropical Sc maxima are too far offshore.
4. Otherwise, GFS+MOM makes an excellent climate model



ANN
NCEP_GFS (yrs 11-50)
Total cloud
mean= 48.01
percent
Min = 5.73 Max
ISCCP D2
Total cloud
mean= 66.68
percent
Min = 11.04 Max = 96.
NCEP_GFS (yrs 11-50)
TOA LW cloud forcing
mean= 17.85
W/m²
Min = −0.15 Max
ANN
NCEP_GFS (yrs 11-50)
TOA SW cloud forcing
mean= −25.32
W/m²
Min = −118.28 Max
ANN
CERES2
TOA LW cloud forcing
mean= 29.90
W/m²
Min = −5.11 Max
CERES2
TOA SW cloud forcing
mean= −47.07
W/m²
Min = −120.79 Max

Sc-Cu CPT model improvement work

1. Rejuvenated GFS single-column model and used it to test PBL, cloud fraction and shallow cumulus schemes in standard GCSS benchmark Sc and shallow Cu cases – showed ShCu scheme overactive, underentraining, overprecipitating (Fletcher et al. 2014 *GMD*).
2. Showed that LES-suggested changes to shallow cumulus parameterization also increase global cloud cover (Fletcher et al. 2014).
3. Developed TKE dissipation heating scheme for GFS (Han et al. 2015, *Wea. Forecasting*, submitted)
4. Developed 'hybrid EDMF' scheme (Han et al. 2015)

- A basket of moist physics changes including 3 and 4 became operational in GFS in Jan. 2015.

Goals of new Clouds CPT (2014-2017)

Building on previous results of Sc-Cu CPT,

- Implement a moist Eddy-Diffusion Mass-Flux (EDMF) scheme within GFS that improves operational weather and coupled climate metrics (JPL, NCEP, UW).
- Improve global cloud climatology of GFS+MOM through better cloud microphysical and macrophysical schemes (NCEP, UW).
- Compare GFS-forecast clouds with versions of GFDL climate model run in initialized weather forecast mode (NCEP, GFDL, UW) to understand relative advantages of the moist physics parameterizations in the two models.

Clouds CPT Result 1: Hybrid-EDMF scheme in GFS

Han et al. (2015), submitted to *Wea. Forecasting*

Idea: Replace operational EDCG scheme with EDMF scheme for strongly unstable boundary layers to promote faster convective boundary layer growth over land, improving convective initiation and precipitation skill.

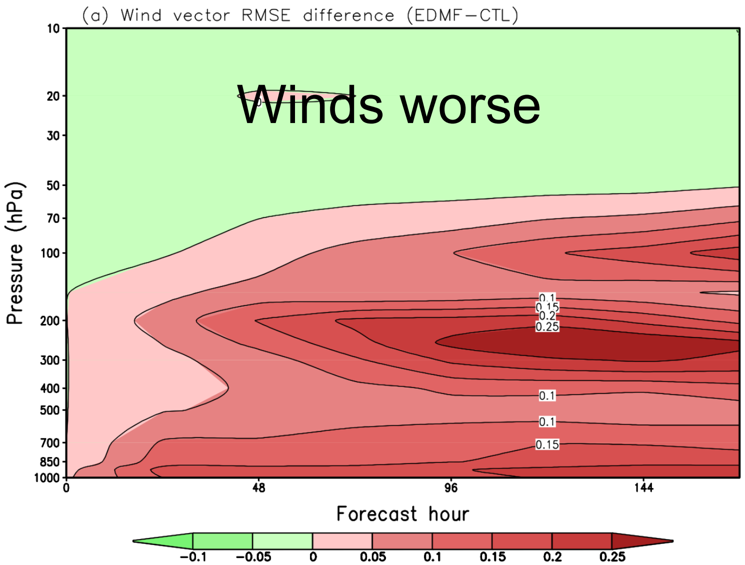
EDMF: Mass-flux representation of strongest updrafts, treating θ and q as advected scalars φ (Moist: θ_l and q_t).

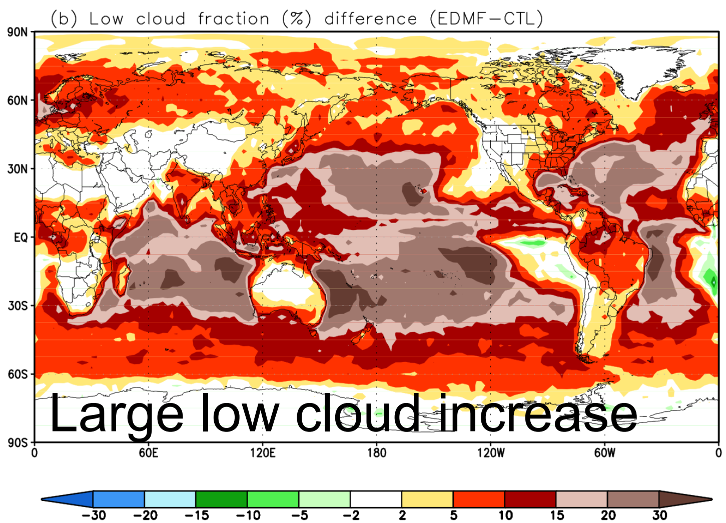
$$\overline{w'\phi'} = -K\frac{\partial\bar{\phi}}{\partial z} + M(\phi_u - \bar{\phi})$$

Also includes TKE dissipation heating.

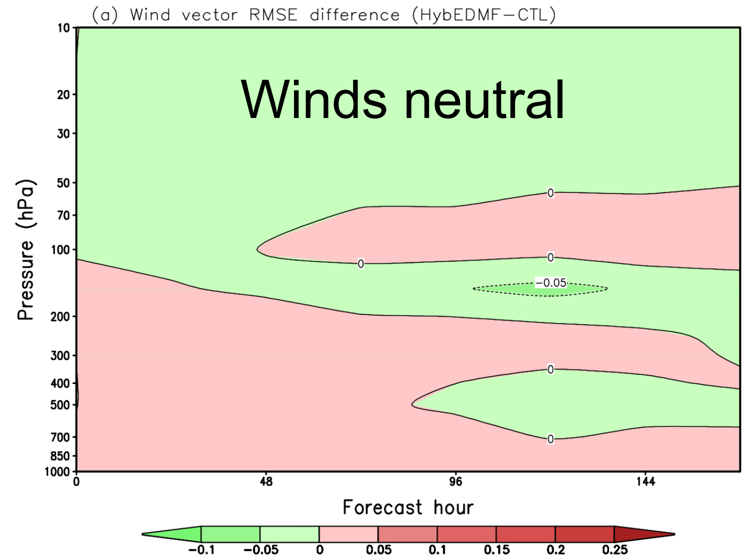
Biases vs. GFS-O

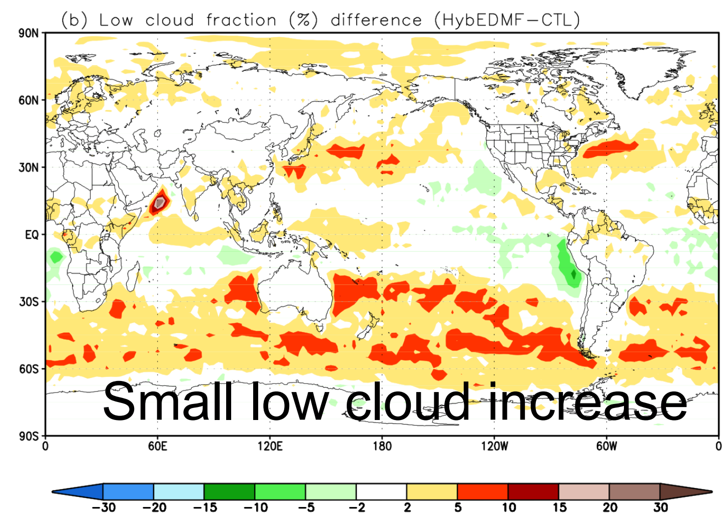
EDMF everywhere



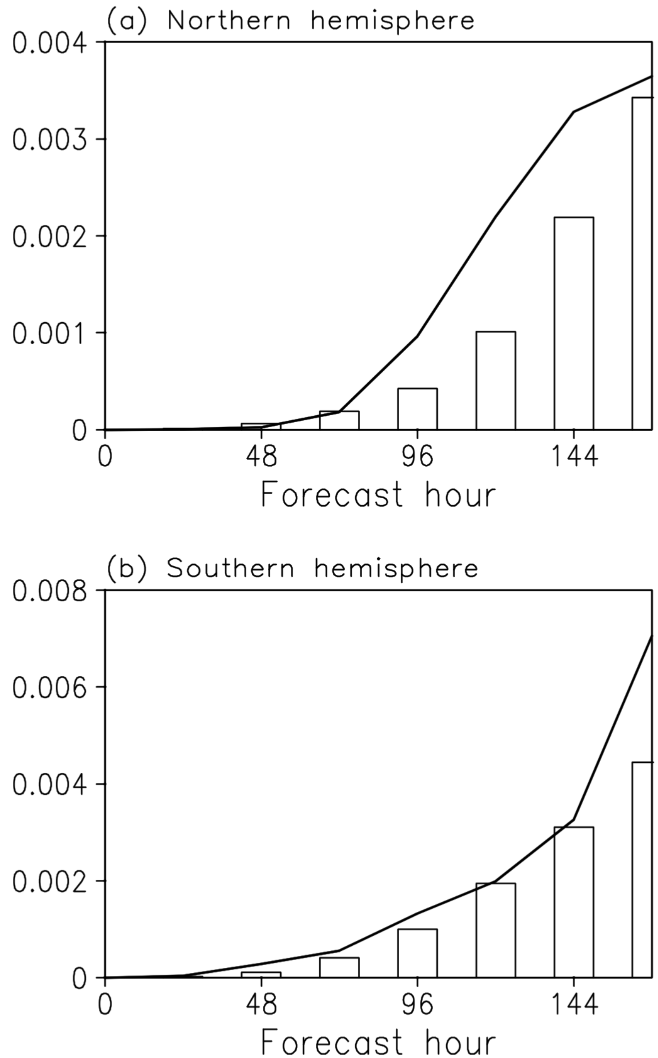


Hybrid EDMF





Hybrid-EDMF plus other GFS changes increase 500 hPa anomaly correlation vs. operational GFS



For this reason, these new physics changes became operational in Jan. 2015

Result 2: Forecast-mode comparison of GFS, GFDL

Goal: Can we learn by comparing clouds in models and obs when large-scale dynamics haven't yet drifted far from reality?

Pilot period: July 2013

GFS: Daily forecasts with operational (T574L64), pre-op hi-res (T1534L64) versions (O and P)

GFDL: Daily 3-day forecasts from operational GFS analysis using AM3 (2° L48) and AM4a2 (pilot version, ~ 1° L48)

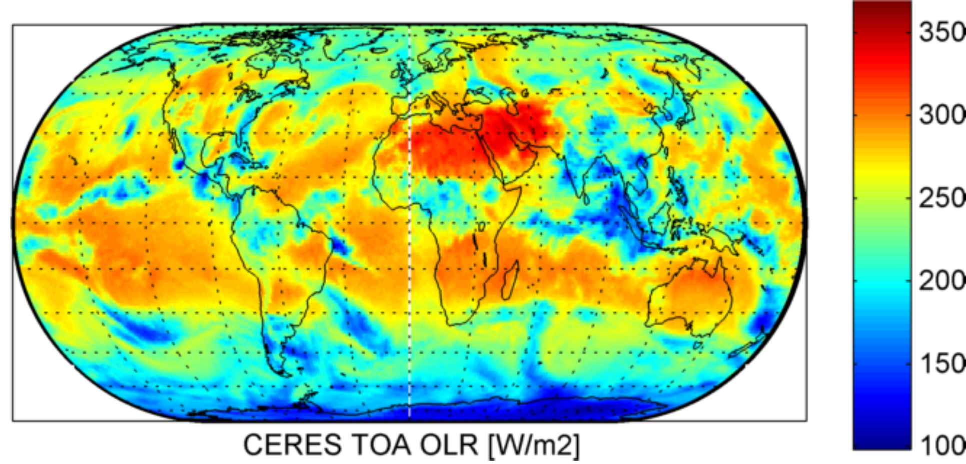
Obs: CERES daily-average estimates of OLR and RSW

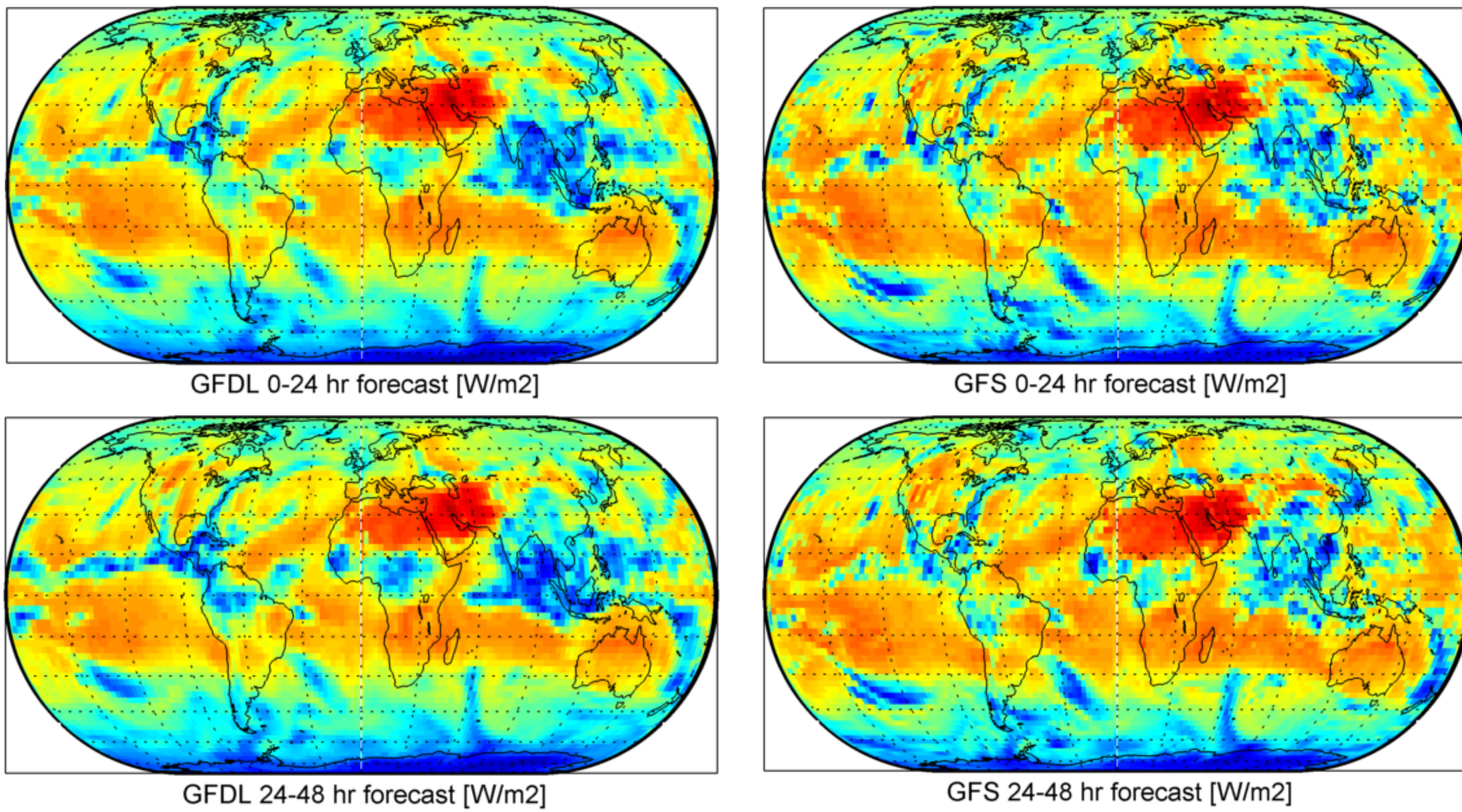
Caveat: Possible spinup issues, esp. for GFDL

Results packaged into netCDF by NCEP and GFDL, analyzed by Chris Jones of UW.

July 2, 2013 OLR
AM3 and GFS-O

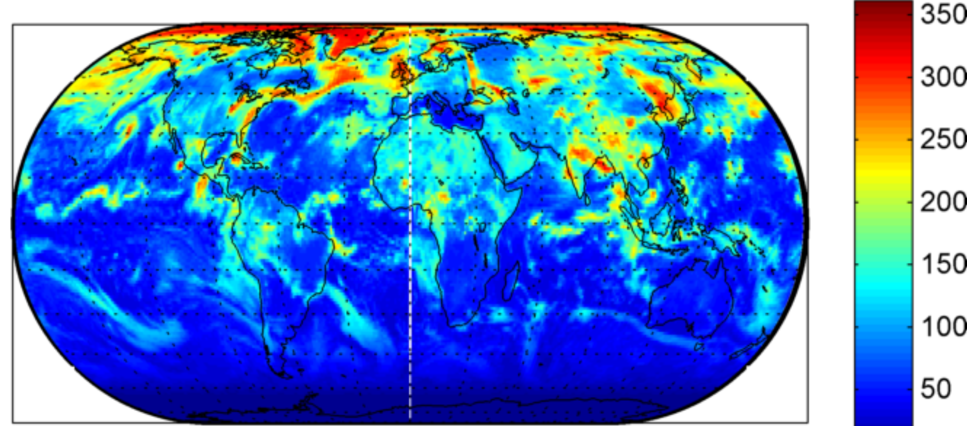
Both models are on the right planet!



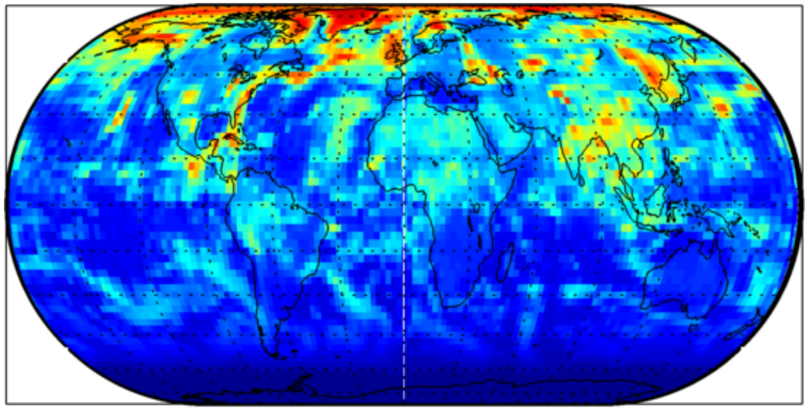


July 2, 2013 RSW
AM3 and GFS-O

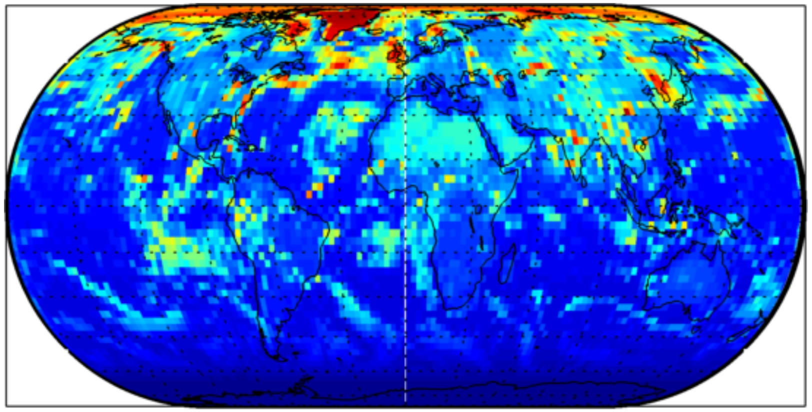
Both models still on the right planet!



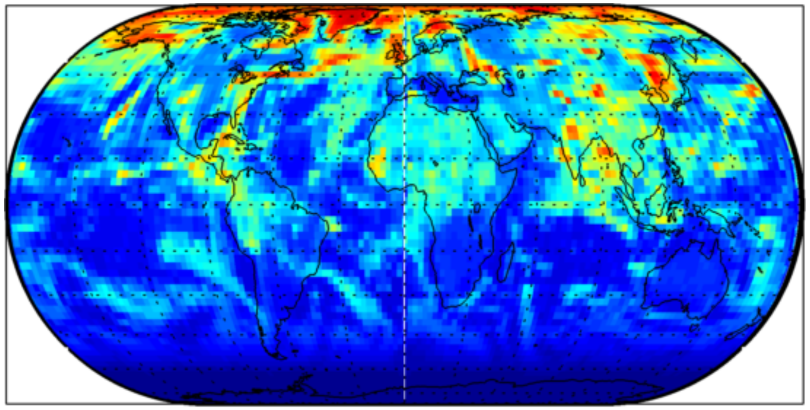
CERES TOA UpSW [W/m2]



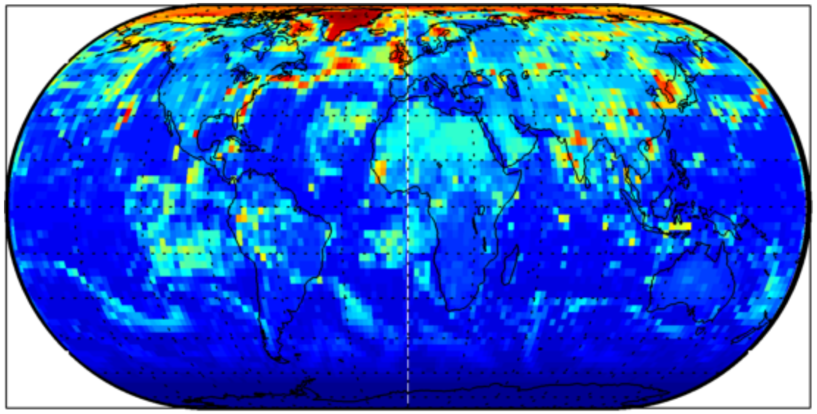
GFDL 0-24 hr forecast [W/m2]



GFS 0-24 hr forecast [W/m2]



GFDL 24-48 hr forecast [W/m2]



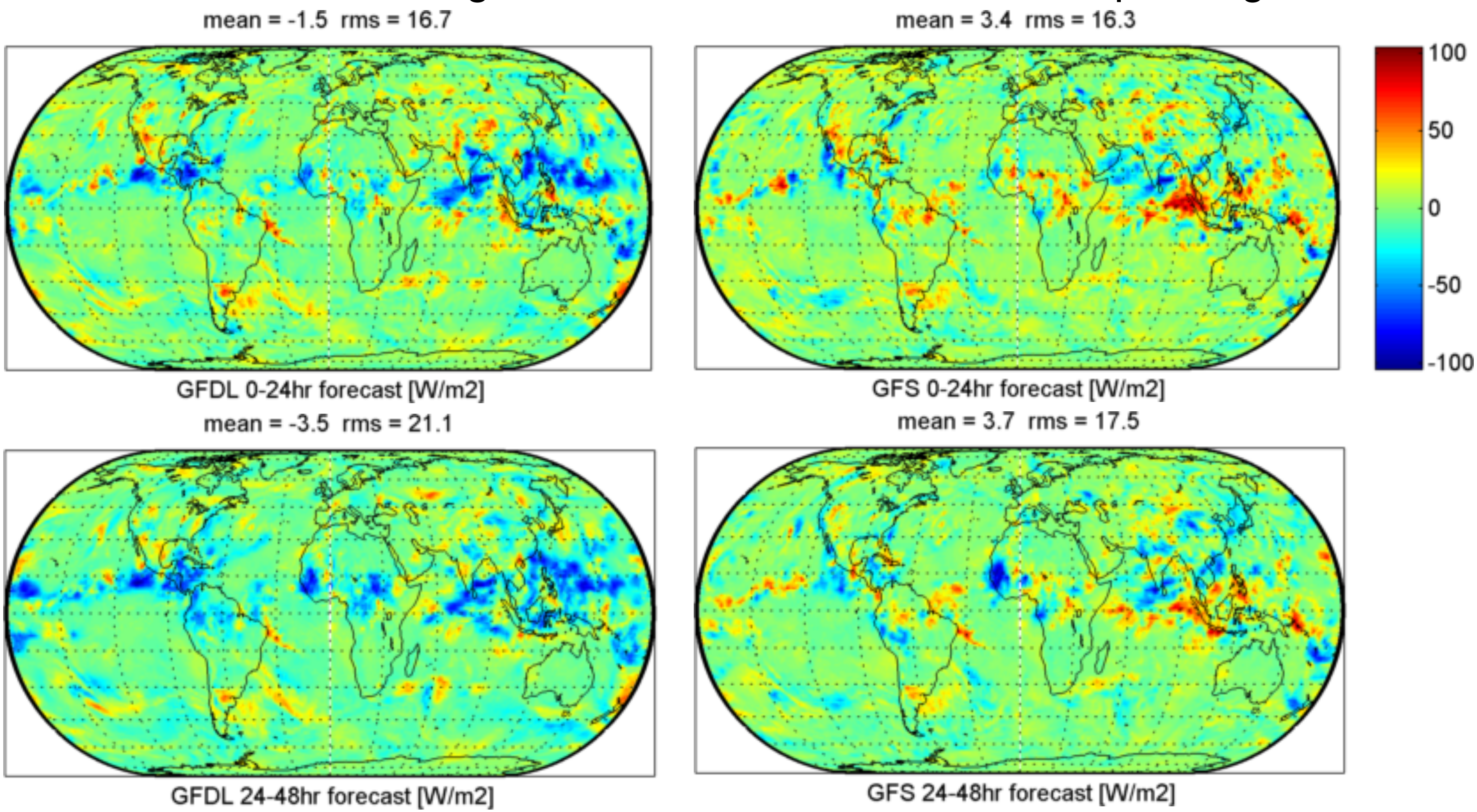
GFS 24-48 hr forecast [W/m2]

July 2, 2013
ΔOLR vs. CERES
AM3 and GFS-O

Models have different regional bias patterns which don't vary with forecast lead

AM3: Too much ITCZ high cloud

GFS: Too little warm pool high cloud



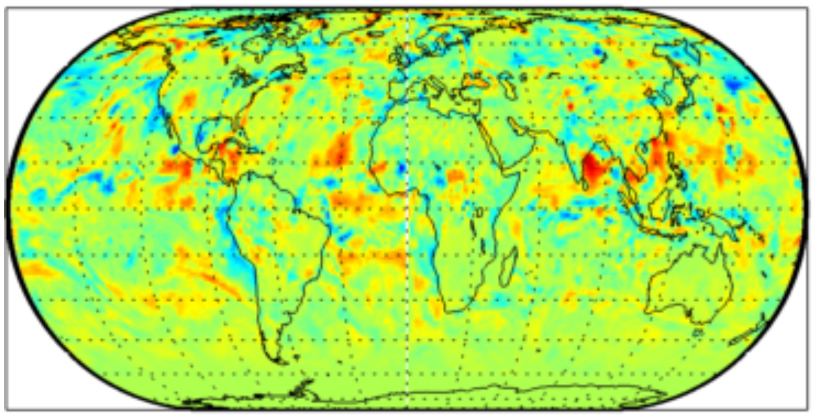
July 2, 2013
ΔRSW vs. CERES
AM3 and GFS-O

Models have different regional bias patterns which don't vary with forecast lead

AM3: Too little coastal Sc

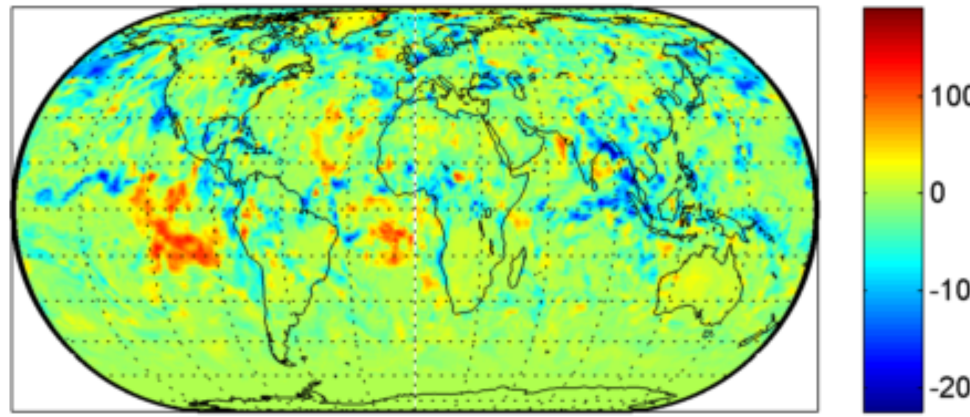
GFS: Too little cloud almost everywhere

mean = 1.5 rms = 30.8



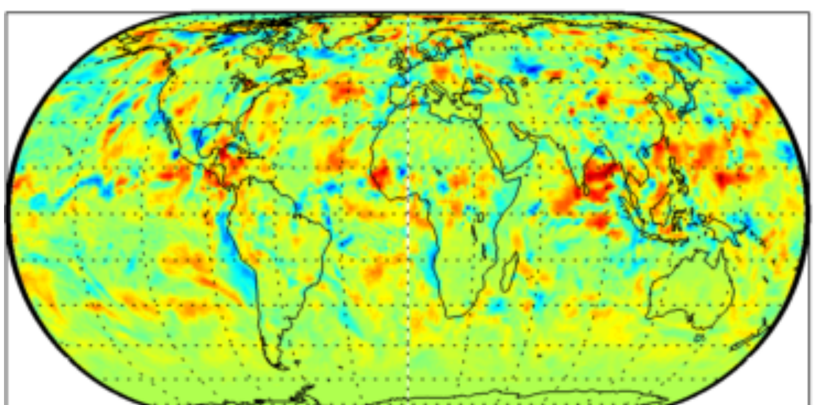
GFDL 0-24hr forecast [W/m2]

mean = -12.5 rms = 36.5



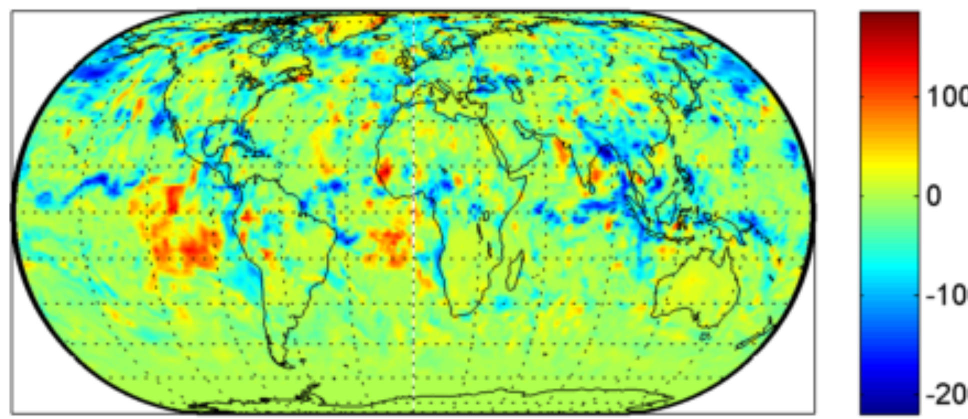
GFS 0-24hr forecast [W/m2]

mean = 4.7 rms = 34.4



GFDL 24-48hr forecast [W/m2]

mean = -14.3 rms = 37.2

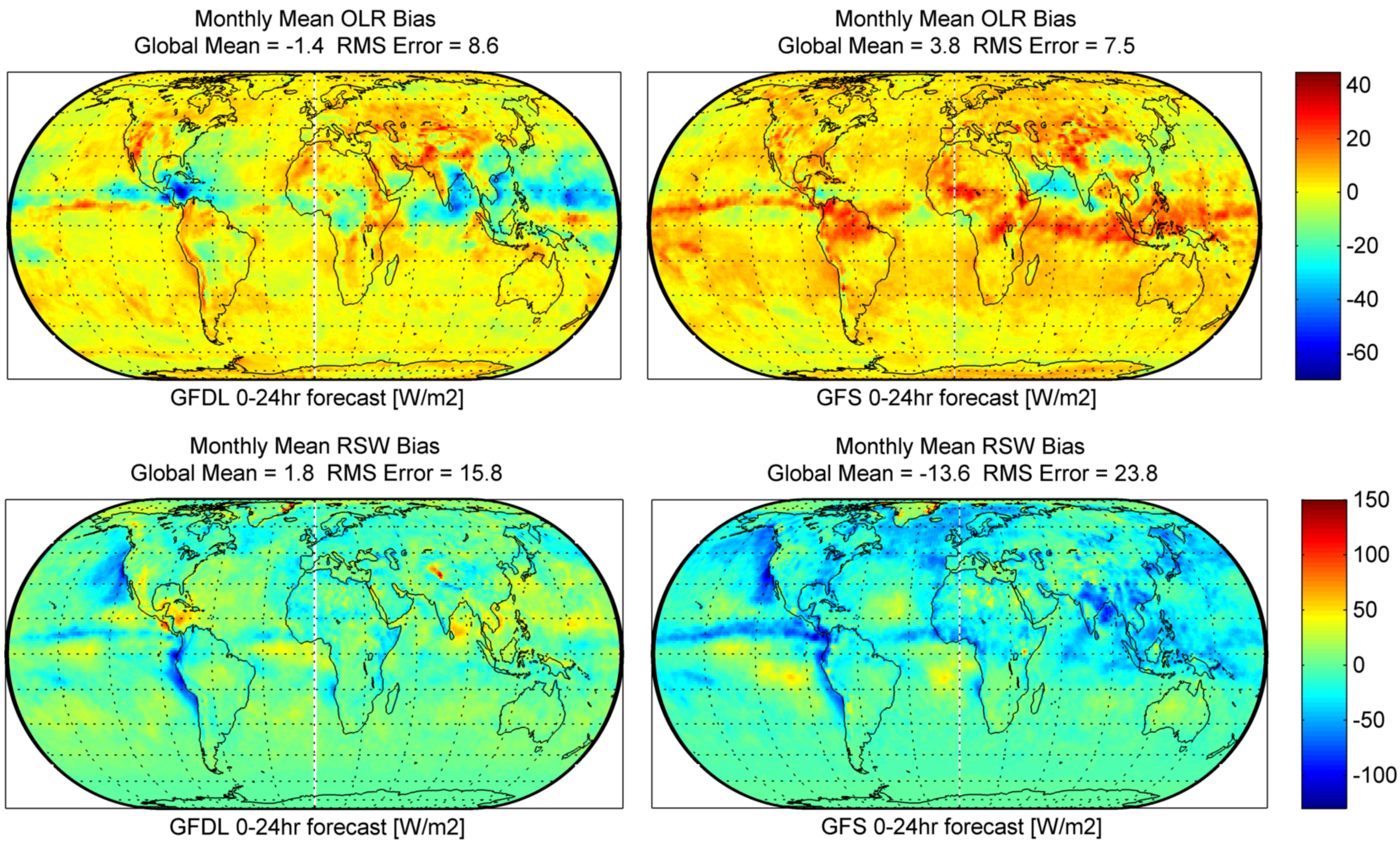


GFS 24-48hr forecast [W/m2]

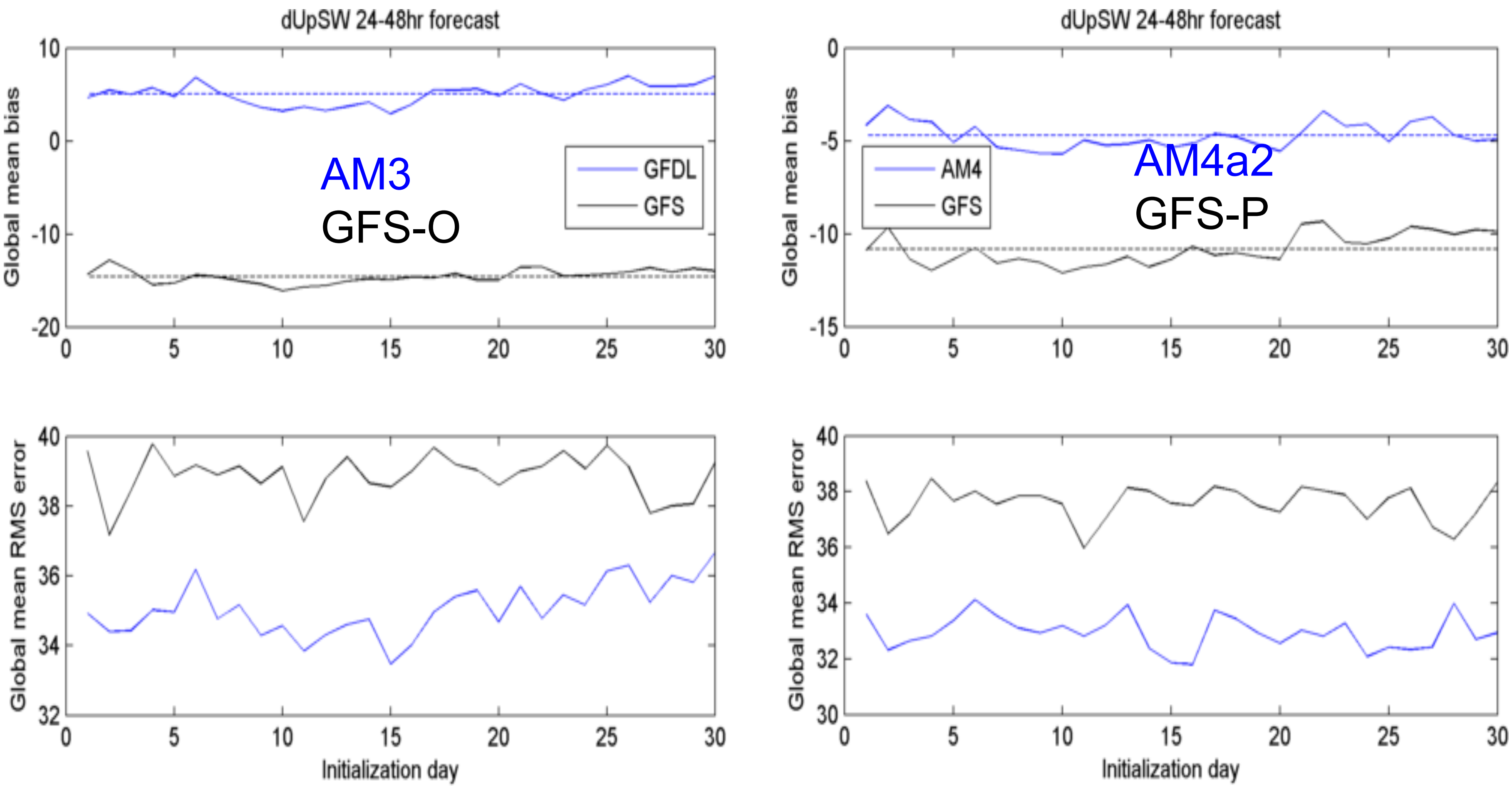
Other days all look rather similar

…summarized with monthly-mean 0-24 hr bias patterns

GFS has 10 W m^{-2} global radiative heating imbalance



Daily global bias and spatial RMSE: Model version comparisons



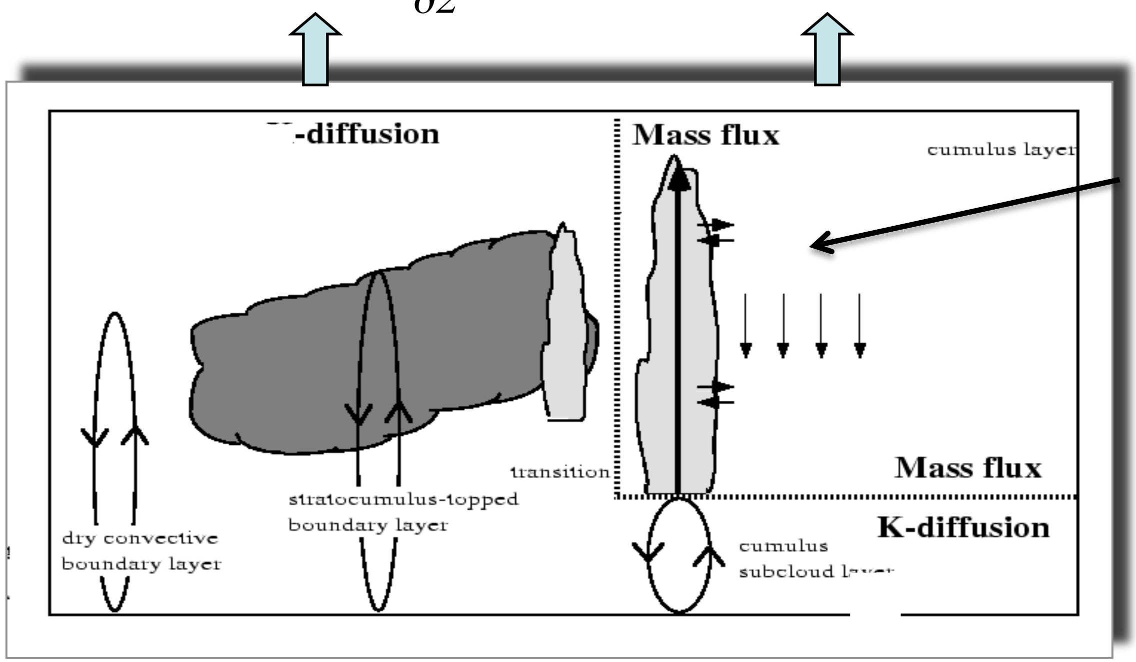
- Both prototype versions have slightly reduced RSW RMSE
- Mean biases also slightly reduced in GFS-P vs. GFS-O
- Still thinking about how best to use these results.

Work in progress

(1) GFS implementation of 'moist' EDMF:

Transport moist variables $\varphi = \theta_l$ and q_t, dealing with Sc-top entrainment and merging with mass-flux Cu param. Much more challenging but rewarding to get right than dry EDMF.

$$\overline{w'\phi'} \cong -K\frac{\partial\overline{\phi}}{\partial z} \qquad \overline{w'\phi'} \cong M(\phi_u - \overline{\phi})$$



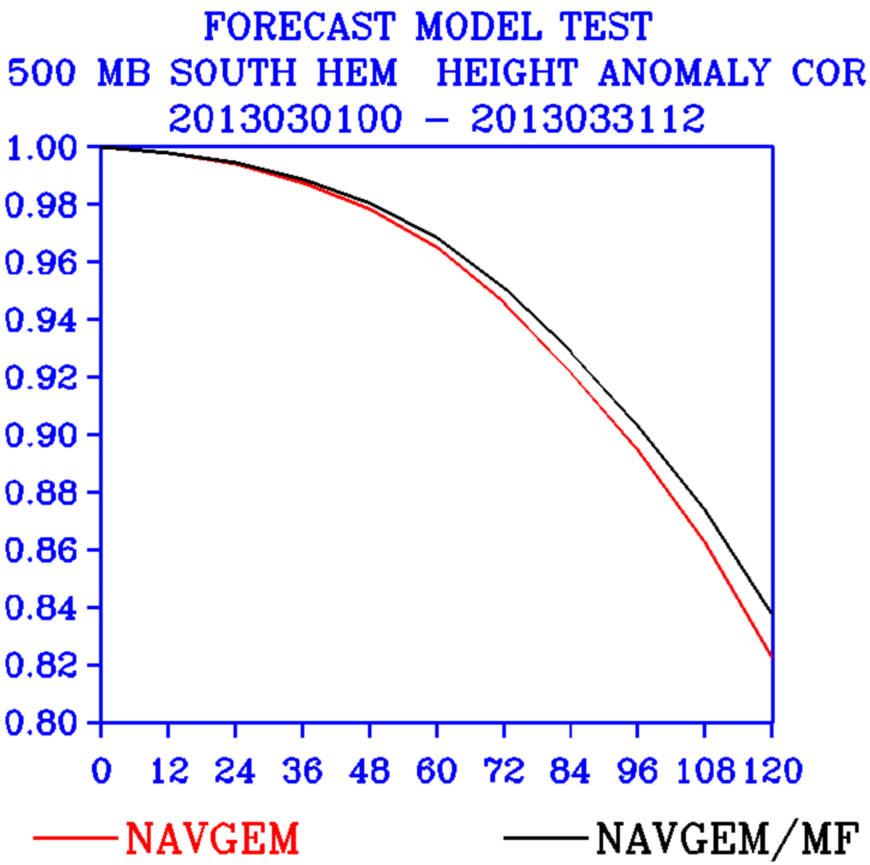
JPL EDMF uses multiple Cu plumes with stochastic entrainment

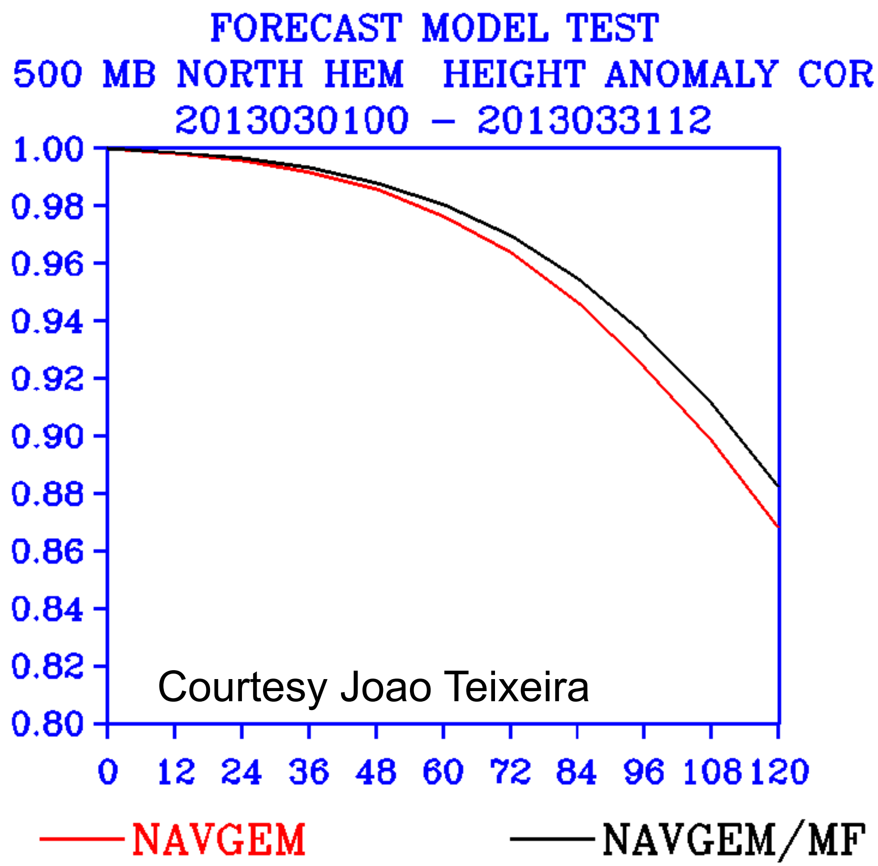
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Stochastic Moist EDMF implementation into US Navy global model NAVGEM

Southern and Northern Hemisphere 500 hPa Anomaly Correlations for NAVGEM and NAVGEM with EDMF - Full data assimilation (T359L50)





Stochastic EDMF significantly improves Navy NAVGEM model

(2) Improving global clouds/radiation in GFS

Not just a boundary layer problem!

Global cloud biases implicate cloud micro/macrophysics

Strategy:

1. Implement fractional cloudiness in WSM5 scheme from WRF and test in GFS.
2. Learn from forecast-mode comparisons of clouds in GFS and AM versions.
3. Collaborate closely with other CPTs and CFSv3 development team (implementing metrics, standardizing global and SCM testing, ‘test-harness’ for coupled seasonal forecasts from 2 weeks to one year).