

Empirical Correction of General Circulation Models

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COLA Model: M. Zhao, P. Dirmeyer, B. Kirtman

GFS Model: Xiaosong Yang, Hua-Lu Pan, Cathy Thiaw

Empirical Correction Strategies

$$\dot{\mathbf{x}} = g(\mathbf{x}) + \epsilon$$

tendency *GCM* *error*

1) Nudging based on long term biases:

$$\epsilon = -bias / \tau_R$$

2) Relaxation:

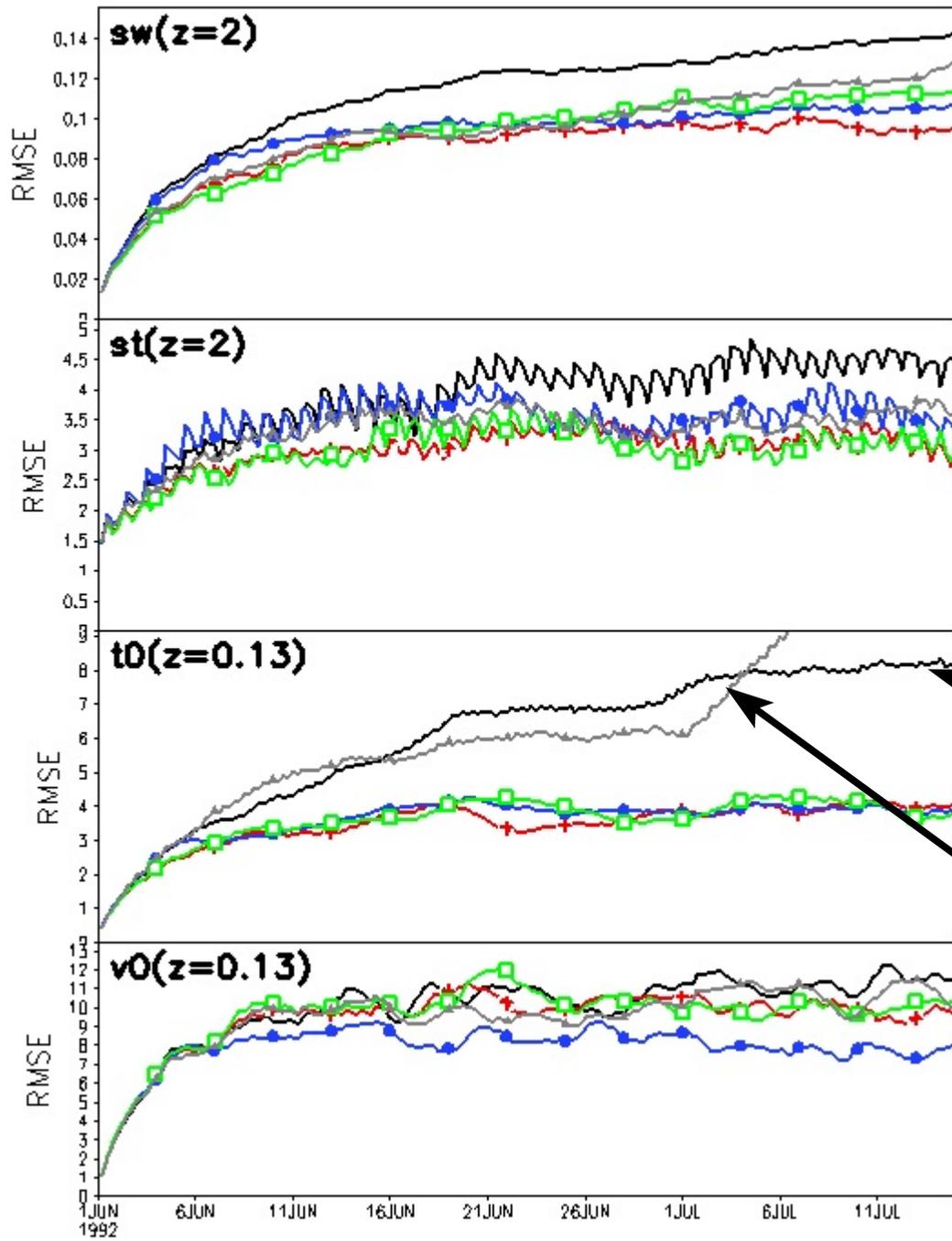
$$\epsilon = (x_c - x) / \tau_R$$

3) Nudging based on tendency errors:

$$\epsilon = \left(\frac{error}{\tau} \right)^t$$

Experiments with COLAv3.2

- ϵ estimated from 6, 12, 18, 24 hour forecasts
- ϵ for U, V, T, SW, ST, each grid, 21 of 28 levels
- Training period: Jun-Aug, 1982-1991
- Verification Period: Jun-Aug, 1992-2001
- Atmospheric Analysis: NCEP Reanalysis
- Land-surface Analysis: GOLD



RMSE COLA Model

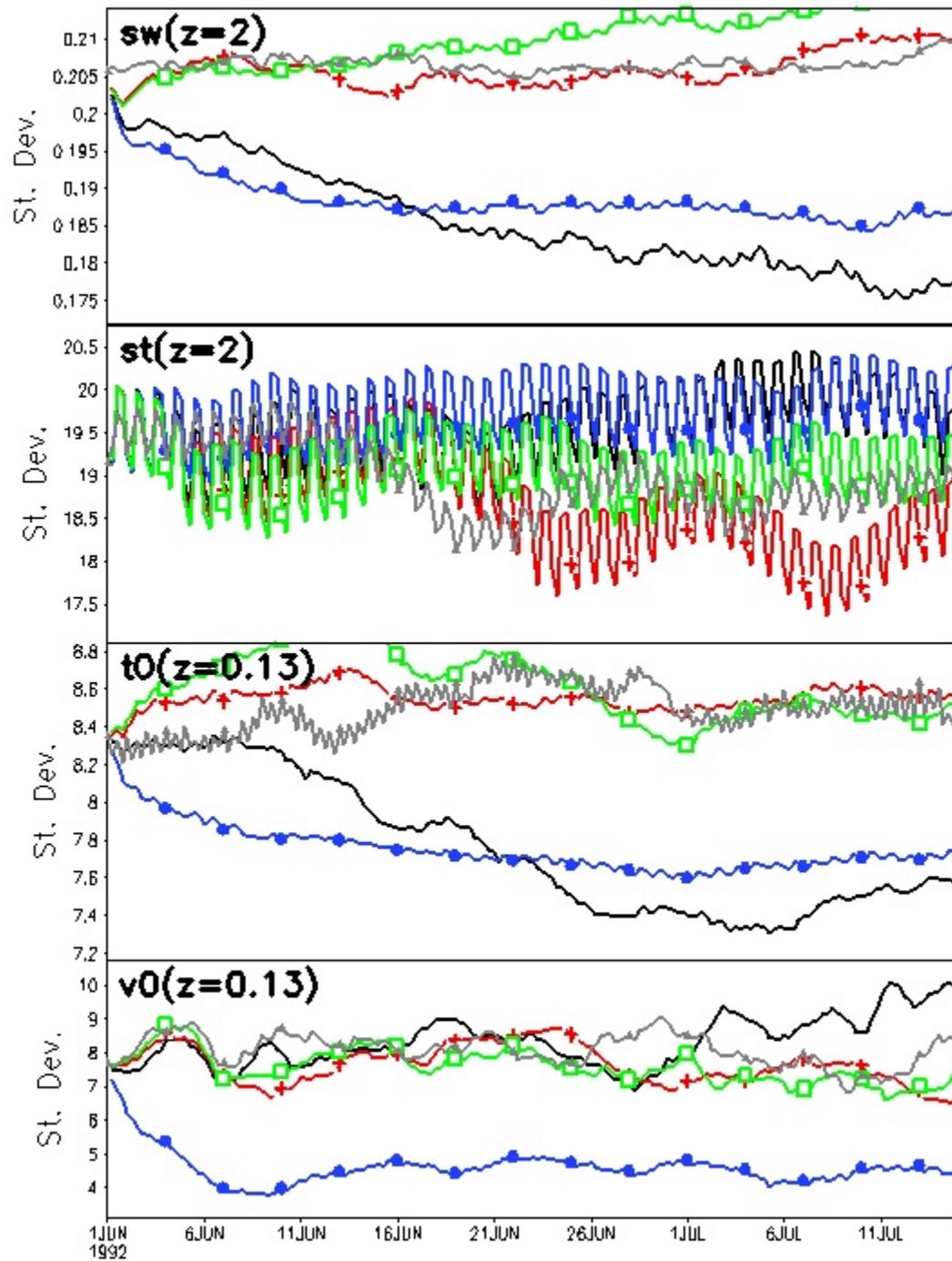
4 empirical correction strategies

Black= control

color=empirical correction

Control

Nudging Based on Long-Term Biases

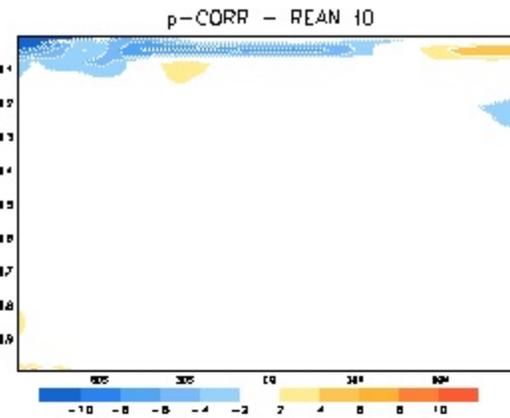
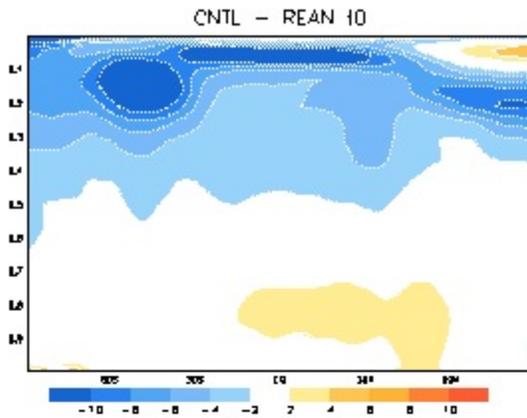


Spatial Variance in COLA model

Observed

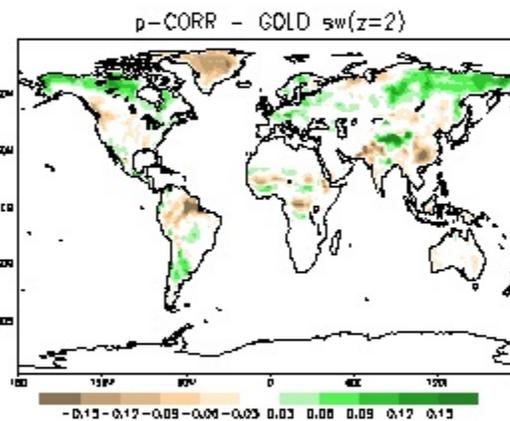
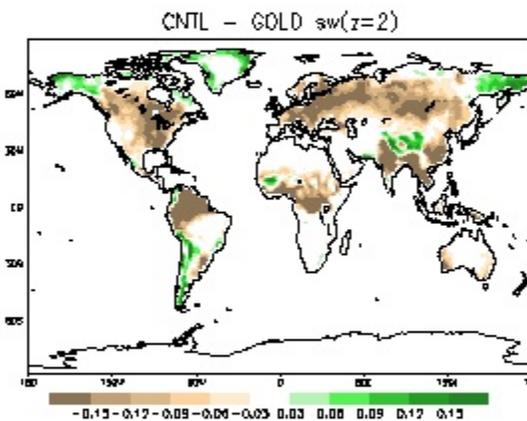
Relaxation

Control



August Mean Error in Control vs. Corrected

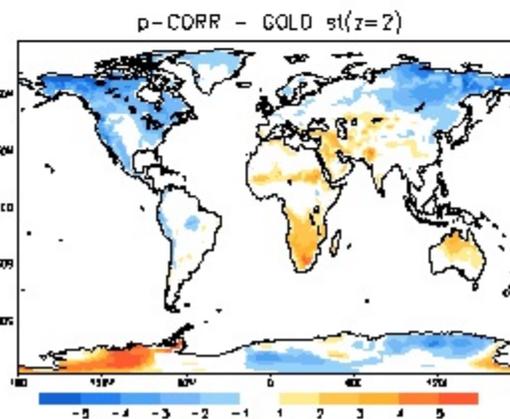
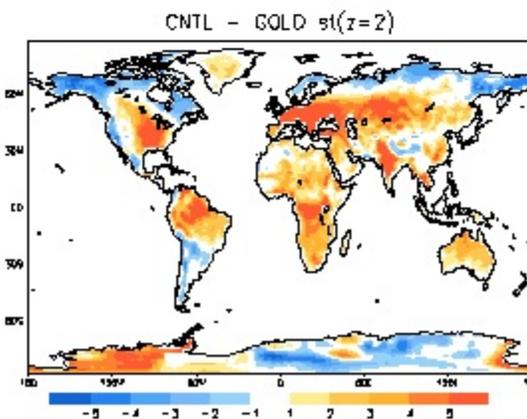
COLA model



Nudging based on tendency errors

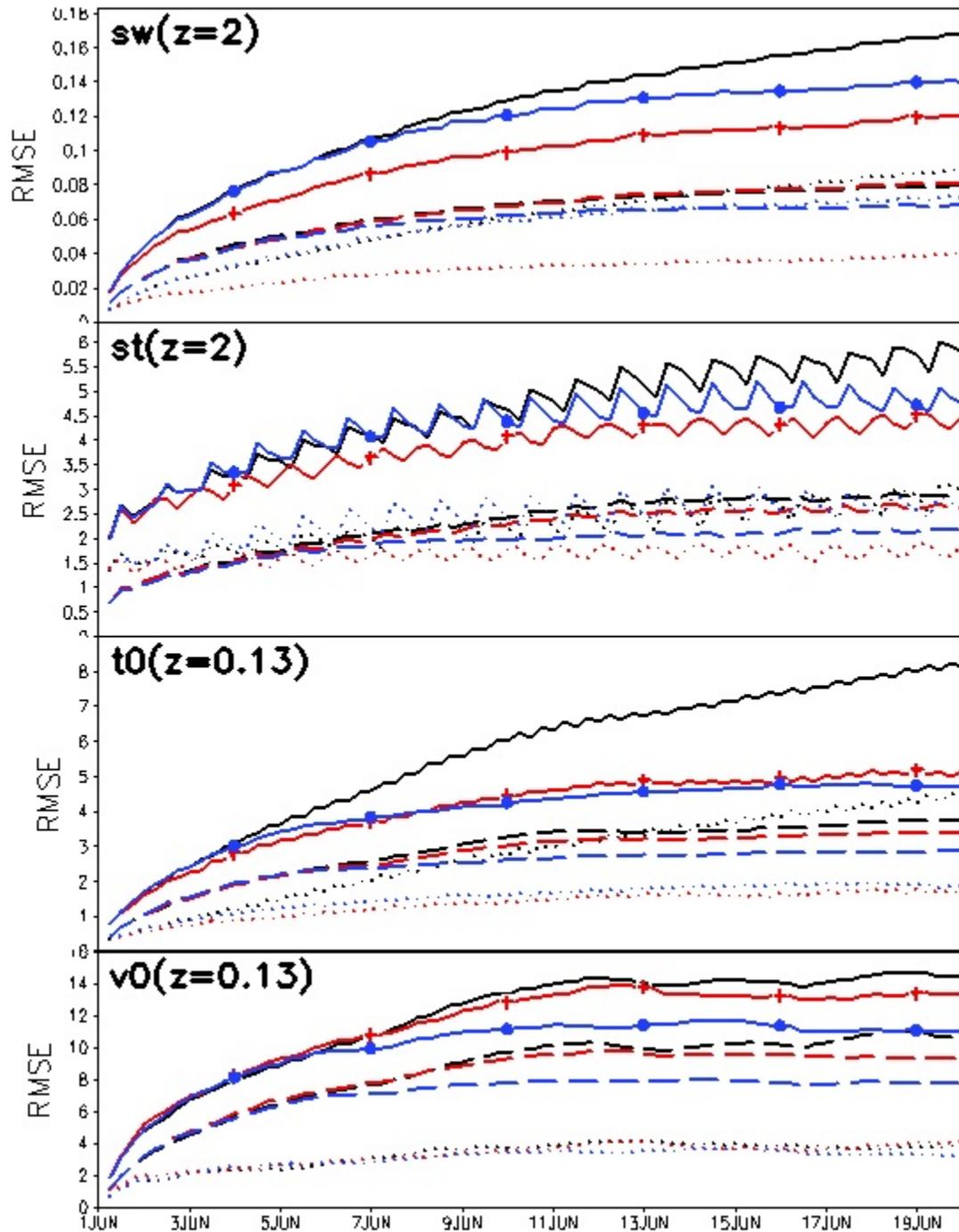
Conclusions

1) removes cold bias in atmosphere



2) removes warm-dry bias in land

3) hardly influences cold-wet biases



COLA Model
 Error Decomposition:
 Total = Bias + Random

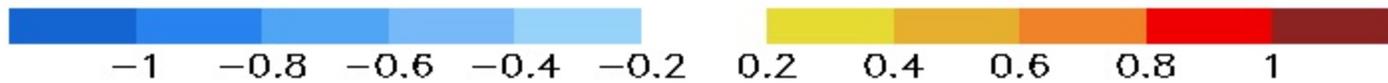
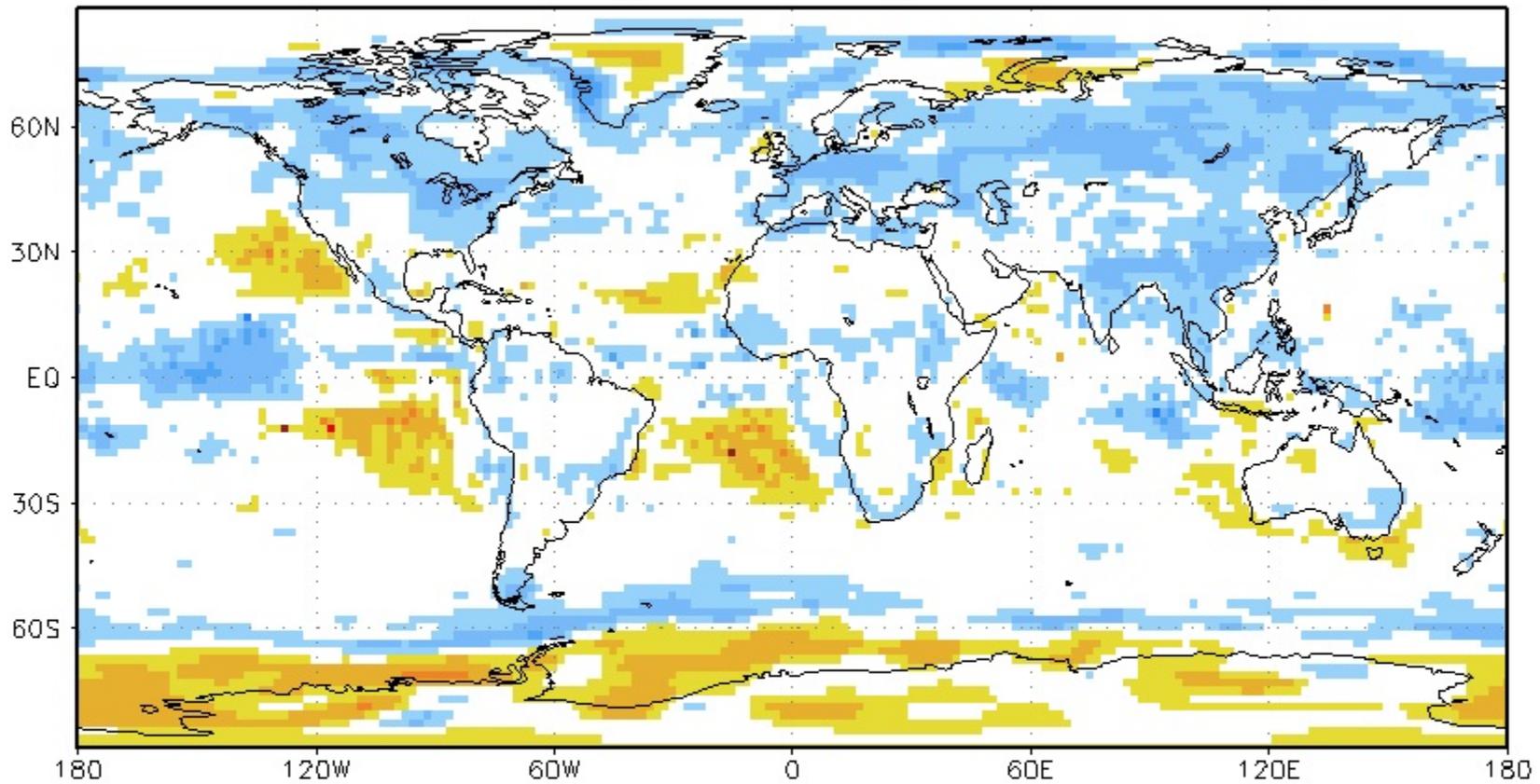
Dotted: Bias
 Dashed: Random
 Solid: Total

Black: Control
 Blue: Relaxation
 Red: Nudging

Conclusions

- 1) Nudging reduces bias.
- 2) Nudging does not reduce random errors.

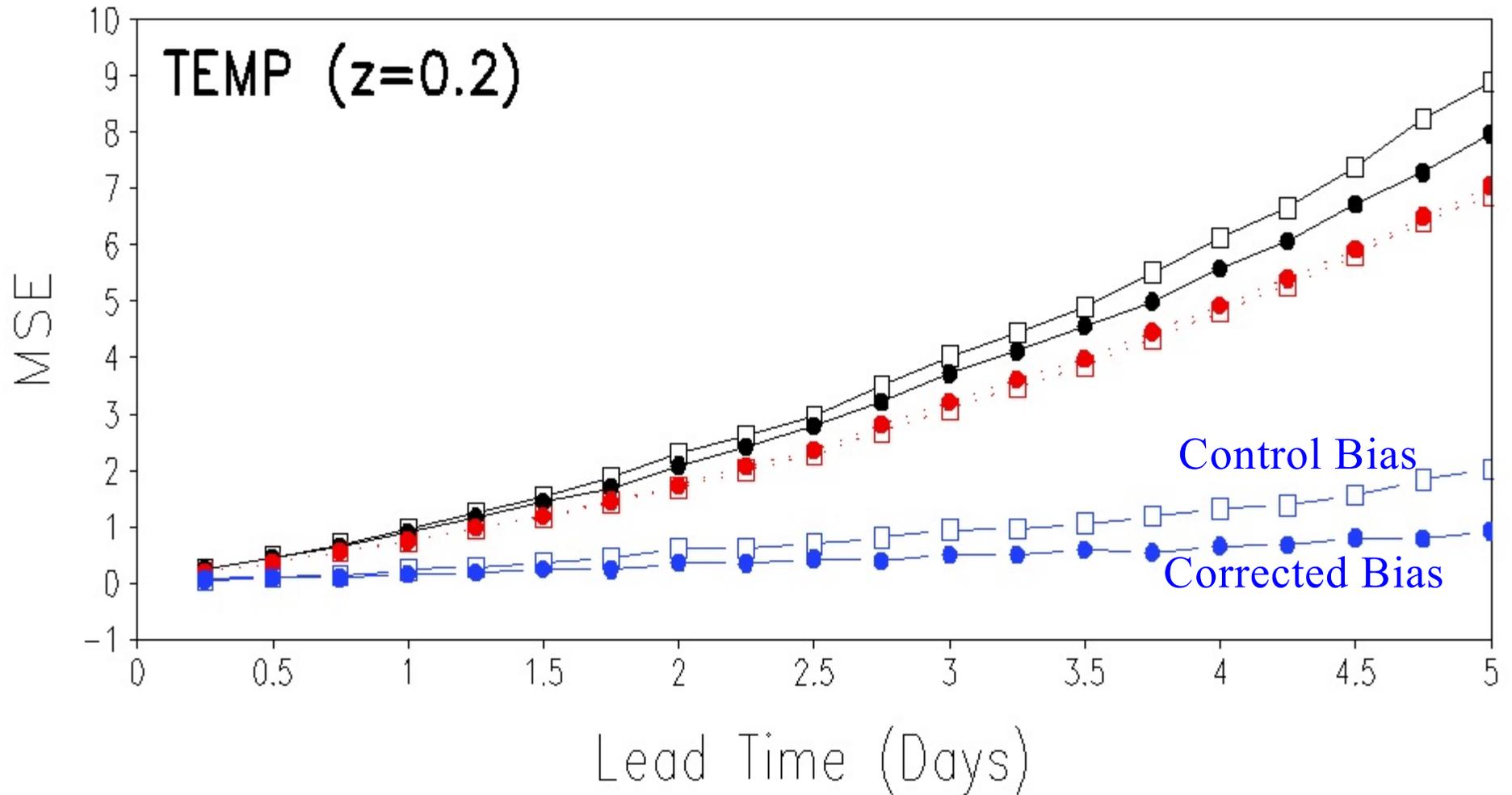
Correlation Between IC and Correction Forcing t0, Z=1, 2aug - 30aug, 1982-1991, j



Experiments with GFS

- Model: Current GFS, May 2007, σ -coordinate
- ϵ estimated from 6, 12, 18, 24 hour forecasts
- ϵ for U, V, T, Q, Ps, T62 coefficients, all levels
- Training period: June 2005-Jan 2007
- Verification Period: Jan 2006, 0.25 - 5d forecasts
- Verifying Analysis: GFS Analysis

GFS Mean Square Error vs. Lead Time (N. Hem., January 2006)



Previous Studies

General Methodology and Idealized Studies

- Leith (1978)
- Faller and Lee (1975)
- Faller and Schemm (1977)

State-Independent Correction Improves Random Error

- Johansson and Saha (1989)
- Achatz and Branstator (1999)
- Yang and Anderson (2000)
- Danforth, Kalnay, Miyoshi (2007)

State-independent Correction Does NOT Improve Random Error

- Saha (1992)
- DelSole and Hou (1999)
- DelSole, Zhao, Dirmeyer, Kirtman (2007)

Hypothesis

Bias correction improves random error only if bias is “large”

Large Bias/Improved Random Error:

- Achatz and Branstator (1999): 2-layer filtered model vs. GCM
- Yang and Anderson (2000): OAGCM had poor NINO3 skill
- Danforth, Kalnay, Miyoshi (2007): 3L-QG model vs. 7L-PE

Small Bias/Same Random Error:

- Saha (1992): NMC model had small bias (10% of total)
- DelSole and Hou (1999): contrived state-dependent error
- DelSole, Zhao, Dirmeyer, Kirtman (2007): small bias (<10%)
- Yang and DelSole (2007): GFS has small bias

Summary

1. Nudging based on tendency error clearly outperforms relaxation methods and nudging based on long-term biases.
2. Empirical correction reduces statistically significant biases in the COLAv3.2 and GFS temperature forecasts.
3. Wind biases were marginally corrected, but are small anyway.
4. Moisture biases could not be corrected significantly, but also were not amplified.
5. Empirical correction had no significant impact on random errors, or on the skill of monthly means.
6. Simple state-dependent corrections are not effective.