Diagnosing the Sensitivity of CAM5’s MJO to Physical Parameters

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Motivation and Approach
- Modelers would like to understand how their climate models could better simulate an MJO
- We systematically explore the dependencies of CAM5’s MJO simulation on uncertain parameters, with a “perturbed-parameter ensemble” technique
  - To what extent, do the parameters control the interactions of the parameterized processes and influence the MJO?
  - Are better MJOs within tuning ranges? Or are new parameterizations needed?
- We more fully explore the range of model MJO behaviors by perturbing uncertain parameters in CAM5 physics

Perturbed Parameter Ensemble (PPE)
- CAM5.1 @ 2° resolution
- 5-year prescribed SST simulations (2000-05)
- Simultaneously perturb 22 parameters using Latin Hypercube Sampling (LHS)
- # of simulations = 1100
- Simulations were performed for DOE’s Climate Science for a Sustainable Energy Future project

Parameters Perturbed
- Large-Scale Cloud
  - Lcc:
    - mom_5T:
      - 0.005
    - mom_4T:
      - 0.005
    - mom_3T:
      - 0.005
- Aerosol BC
  - Lc:
    - mom_5T:
      - 0.005
    - mom_4T:
      - 0.005
    - mom_3T:
      - 0.005
- Snow:
  - zmconv_c0:
    - 0.01
  - zmconv_alfa:
    - 0.01
- Deep Conv.
  - zmconv_alfa:
    - 0.01
  - zmconv_alfa:
    - 0.01

MJO Metrics
- From the CLIVAR MJO Task Force (2009):
  1. Hovmöller: Correlation coefficient of model with observations for patterns of lead-lag correlation coefficients of band-passed filtered 5°N-5°S averaged precipitation with that in the Indian Ocean (70°-90°E)
  2. Power Spectra: East-west power ratio of precipitation variance in wavenumbers 1-5 and periods 20 – 90 days

MJO in “UQ-Rec”
- Altering only the 4 parameters that influence the MJO yields the best MJO simulation

Which parameters affect CAM5’s MJO?

What parameter values would improve CAM5’s MJO?

Methods
- Fit a mathematical “surrogate” model that relates the predictands (metrics of MJO simulation) to the predictors (physics parameters perturbed)
- Use “surrogate” model to tell you which predictors have influence and which are immaterial
- Create a new “surrogate” model with only the important predictors
- Use the new “surrogate” model and the observed predictand values to create likelihood estimates of the predictions

Specific techniques used
- Sparse Polynomial Chaos Expansion (3rd order) (PCE)
- Random Forest Regression (ET) (Breiman 2001)

Deep convection parameters matter
- Relative Influence of Parameters on Hovmöller and Power Spectra Metrics

Is CAM5’s MJO like the real MJO?
- Observational analyses have demonstrated that the MJO has a specific structure of moisture anomalies whereby the low-level moisture builds up to the east of the precipitation maximum. This is thought to be important for the eastward propagation of the MJO.

Moisture Anomalies in a Composite MJO
- Zonal cross-section of moisture anomalies regressed onto band-passed filter precipitation at 120°E

But is the mean climate improved?

Mean Climate Bias and Root-Mean-Square Errors
- With respect to observations of 10-year DJF means

Conclusions
- Through analysis of a large Perturbed-Parameter Ensemble, we determined which physical parameters had the greatest influence on CAM5’s simulated MJO
- Altering the values of only the parameters that influence the MJO to their recommended values yielded the best simulation MJO simulation
- However, the simulation with the best MJO had significantly degraded radiation field, suggesting that other changes would be necessary to CAM5’s physical parameterizations if this guidance were to be used in the default model