GEOS-5 system developments for decadal climate prediction

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The GEOS-5 AOGCM for CMIP5

| GEOS-5 AGCM | 2° lat. x 2.5° lon. X 72L  
|            | surface to 0.01hPa  
|            | Finite Volume Dynamical Core  
|            | RAS convection scheme with stochastic Tokioka  
|            | Bacmeister et al. prognostic clouds  
|            | Chou-Suarez radiation  
|            | Louis and Lock PBL schemes  
|            | Monin-Obhukov type surface turbulence scheme  
|            | Catchment Land Surface Model  
|            | CMIP5 prescribed forcings  
|            | Lin et al. (2004)  
|            | Bacmeister et al. (2006)  
|            | Moorthi and Suarez (1992)  
|            | Lock et al. (2000)  
|            | Louis (1982)  
|            | Chou and Suarez (1999)  
|            | Chou et al. (2001)  
|            | Koster et al. (2000)  
| GOCART Aerosols | Dust: 5 bins  
|                | Sea-salt: 5 bins  
|                | Organic carbon: hydrophobic & hydrophilic tracers  
|                | Black carbon: hydrophobic & hydrophilic tracers  
|                | Sulfates: SO2, SO4, DMS, MSA  
|                | Colarco et al. (2010)  
| OGCM: MOM4 | MOM4p1  
|            | 1/2° lat. x 1/2° lon. with 1/4° equatorial refinement  
|            | 40 vertical levels  
|            | Tripolar grid  
|            | z coord; conservative temp., KPP+tidal mixing  
|            | Griffies et al. (2004)  
|            | Large et al. (1994)  
| CICE v4.1 | Sea-ice thermodynamics  
|            | Sea-ice dynamics and advection  
|            | Ridging parameterization  
|            | Hunke and Lipscomb (2010)  

Air-sea coupling interval: 30 minutes
Annual Mean Model Bias

GEOS-5 – Reynolds SST

mean: -0.07
std: 1.86

CCSM4(2°) – Levitus SST

mean: 0.72
rms = 1.62

GEOS-5 – Levitus SSS

mean: -0.44
std: 1.75

CCSM4(2°) – Levitus SSS

mean: -0.45
rms = 1.01

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Annual Mean Equatorial Temperature

Levitus

GEOS-5

CCSM4 (2°)
Annual Zonal Mean Structure

Temperature

Levitus

GEOS-5

CCSM4 (2°)

Salinity

Levitus

GEOS-5

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AMOC

GEOS-5

CCSM4 (2°)
Atmosphere constrained by MERRA every 6 hours
- Precipitation rescaled to GPCP for LSM

Ocean: daily assimilation
- Ensemble Optimal Interpolation (EnOI)
- State dependent localization based on density
- 1960 to present

Sea-ice: daily assimilation of sea-ice concentration used to constrain mixed layer temperature and salinity
Atlantic 30S-30N

Global 30S-30N

EN3 data and analyses courtesy of Simon Good, UKMO

From Yan Xue: RMSD of ocean analyses from EN3 (uncorrected)

(d) Northern Oceans 31N-70N

(c) Trop. Atlantic 30S-30N
Generation of Ensemble Perturbations

- Method: Two-sided breeding
- Norm variable: HC500 (Averaged Temperature 0-500m)
- Norm Regions: Atlantic ocean (100W-20E, 20N-70N)
- Initial BV magnitude: Reduced to 10% of natural variability
- Rescaling Interval: 5 years
EOFs of HC500

(c) 5YR BV : HC EOF 1st 34.32%
(d) 5YR BV : HC EOF 2nd 20.07%

Bred Vectors

Ocean Analysis

(a) EOF-1 14.88%
(b) EOF-3 6.94%
Lagged regression of SST anomaly (from HadISST1.1 1870–2004) on the multidecadal reconstruction of the North Atlantic basin-average SST anomaly. Units are °C per standard deviation of the latter time series from Alvarez-Garcia et al. 2008.

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Leading BV modes and optimal perturbation

Bred Vectors (upper 500 m)

Optimal perturbation from the HadCM3 model (Hawkins and Sutton 2009)
GEOS-5 Decadal Climate Predictions an early look…

- Forecast period : 5 years
- Initialization from 1 December
- Number of hindcasts : 9 (every 5 year from Dec. 1959)
- Number of ensemble members : 2 (+/- pair of 5yr BVs)
- Validating observations : GEOS Ocean Reanalysis
- **No Volcanic emissions**
Climatological Drift - Annual Mean HC500

(a) 1yr Lead Forecast

(b) 2yr Lead Forecast

(c) 3yr Lead Forecast

(d) 4yr Lead Forecast

(e) 5yr Lead Forecast
ACC for Annual Mean Forecast HC500
ACC for Annual Mean Forecast HC500

Dynamical Prediction

(c) 3yr Lead Forecast

(d) 4yr Lead Forecast

(e) 5yr Lead Forecast

Persistence forecast

(c) 3yr Lead Forecast

(d) 4yr Lead Forecast

(e) 5yr Lead Forecast

* 90% significance level masking
Forecast skill of upper ocean heat content

GMAO
HC500
5-yr average

JAMSTEC
HC300
From Mochizuki et al 2010

* 90% significance level masking
HC500

(a) EOF-1

(b) EOF-2

(b) EOF-3

OBS (reanalysis)
Prediction
● Start year of each forecast

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Summary

- GEOS-5 AOGCM performance similar to CCSM4, some deficiencies in high latitudes

- Early look at decadal prediction results from BV generation runs indicate some (?) predictable signal of variability over the subpolar North Atlantic

- Decadal prediction ensemble suite – central (unperturbed) prediction and more ensemble members (re-bred BV, atmospheric perturbation only) have just started

- Output to be served on the ESG node at GSFC; output is CMOR2-ready