An Update on Experimental Climate Prediction and Analysis Products being Developed at NASA’s Global Modeling and Assimilation Office

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APEC Climate Symposium
“Harnessing and Using Climate Information for Decision Making”

17-20 October 2011
Honolulu, Hawaii
Outline

• GMAO Prediction and Analysis Products
  – GEOS-5 Model
    • Coupled S-I: US National MME (and APCC MME)
    • AGCM High resolution simulations
  – MERRA Reanalysis
    • atlas of extremes

• WCRP effort: working towards a GDEWS
  – coordination with APCC
  – some science (attribution of heat waves)
NOAA/GFDL dynamics

DOE/LANL sea ice model

GSFC/GOCART/Aerosols

GEOS-5 AOGCM

GMAO physics

GMAO Land surface

NOAA/GFDL ocean

DOE/LANL sea ice model
GEOS-5 Coupled analysis cycle for Initialization of ISI Predictions

Relaxation to atmospheric states from MERRA (6-hourly)
Precipitation corrected to GPCPv2.1 pentads (for LSM initialization)

Initialized States for unconstrained coupled forecasts

GEOS-5 AOGCM integration

AGCM
OGCM

Ocean analysis EnKF & EnOI
Seasonal Hindcast/Forecast Schedule (as per CPC)

<table>
<thead>
<tr>
<th>Month</th>
<th>Day</th>
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<tbody>
<tr>
<td>12</td>
<td>12</td>
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<tr>
<td>12</td>
<td>17</td>
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<td>12</td>
<td>22</td>
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<td>12</td>
<td>27</td>
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<td>1</td>
<td>6</td>
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</tbody>
</table>

**MID JANUARY**

**MID FEBRUARY**

**MID MARCH**

**MID APRIL**

**MID MAY**

**MID JUNE**

**MID JULY**

**MID AUGUST**

**MID SEP**

**MID OCT**

**MID NOV**

**MID DEC**

Blue – dates at which 4 additional ensemble members are produce from breeding or simple differences

Pink – critical dates, as forecasts for these might not be ready by due date specified by CPC as 8th of month;

Nominally ten 9-month predictions per month

Hindcasts generated in the same way for each month 1981-2010
September and October Hindcasts (Nino3)

GMAO GEOS-5 Forecast September 2011 Release

GMAO GEOS-5 Forecast October 2011 Release
## "National" MME

<table>
<thead>
<tr>
<th>Model</th>
<th>Hindcast Period</th>
<th>Ensemble Size</th>
<th>Lead Times</th>
<th>Arrangement of Ensemble Members</th>
<th>Contact and reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFSv1</td>
<td>1981-2009</td>
<td>15</td>
<td>0-8 Months</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; 0Z +/-2 days, 21&lt;sup&gt;st&lt;/sup&gt;0Z +/-2d, 11&lt;sup&gt;th&lt;/sup&gt; 0Z +/- 2d</td>
<td>Saha (Saha et al. 2006)</td>
</tr>
<tr>
<td>CFSv2</td>
<td>1982-2009</td>
<td>24(28)</td>
<td>0-9 Months</td>
<td>4 members (0,6,12,18Z) every 5&lt;sup&gt;th&lt;/sup&gt; day</td>
<td>Saha (Saha et al. 2010)</td>
</tr>
<tr>
<td>GFDL-CM2.2</td>
<td>1982-2010</td>
<td>10</td>
<td>0-11 Months</td>
<td>All 1&lt;sup&gt;st&lt;/sup&gt; of the month 0Z</td>
<td>Rosati (Zhang et al. 2007)</td>
</tr>
<tr>
<td>IRI-ECHAM4-f</td>
<td>1982-2010</td>
<td>12</td>
<td>0-7 Months</td>
<td>All 1&lt;sup&gt;st&lt;/sup&gt; of the month 0Z</td>
<td>DeWitt (DeWitt 2005)</td>
</tr>
<tr>
<td>IRI-ECHAM4-a</td>
<td>1982-2010</td>
<td>12</td>
<td>0-7 Months</td>
<td>All 1&lt;sup&gt;st&lt;/sup&gt; of the Month 0Z</td>
<td>DeWitt (Dewitt 2005)</td>
</tr>
<tr>
<td>CCSM3.0</td>
<td>1982-2010</td>
<td>6</td>
<td>0-11 Months</td>
<td>All 1&lt;sup&gt;st&lt;/sup&gt; of the Month 0Z</td>
<td>Kirtman (Kirtman and Min 2009)</td>
</tr>
<tr>
<td>GEOS5</td>
<td>1981-2010</td>
<td>10</td>
<td>0-9 Months</td>
<td>1 Member every 5&lt;sup&gt;th&lt;/sup&gt; day, 4 additional at end of month</td>
<td>Schubert (Vernieres et al. 2011)</td>
</tr>
</tbody>
</table>

NOAA CTB effort
Oct Starts: Season 3 SST forecast (JFM) – Hindcast Correlations based on 1982 - 2011
Oct Starts: Season 3 Precip forecast (JFM) – Hindcast Correlations based on 1982 - 2011

GEOS-5

MME
High Resolution AGCM Runs

• ½ degree AMIP (Young-Kwon Lim)

• ¼ degree attribution (2010 Snow storms, Chang et al 2011; spring storms/flooding and precursors to tornadic activity)

• 3.5 – 14km: focus on tropical storms (Putman and Suarez 2011)
7 km GEOS-5 Observations
Atlas of Extremes

• Compares MERRA and CFSR and various observational datasets

• VAMOS Working Group on extremes
  http://gmao.gsfc.nasa.gov/research/subseasonal/atlas/Extremes.html (Developed at GMAO by Young-Kwon Lim)

• Characterizing extremes for the recent past over the Americas
Basic climatologies

Precipitation extremes

SPI time series and maps

Precipitation return values based on GEV fits, including impact of ENSO

Various temperature extremes - latest

Data sets: MERRA, CFSR, gridded station obs (CPC, CDC)
Standardized Precipitation Index (SPI)

SPI June 1988

MERRA

SPI over Americas (JUN/1988)

CFSR

SPI over Americas (JUN/1988)

CPC

SPI over Americas (JUN/1988)

CDC

SPI over Americas (JUN/1988)
Towards a Global Drought Early Warning System

• Barcelona Drought workshop (March 2011)
  (http://drought.wcrp-climate.org/workshop/index.shtml)

• Action Items
  – Drought catalog
    • Global assessment of current understanding
  – Experimental global drought early warning system
    • GDEWS workshop: 11-13 April 2012, at ESA-ESRIN, Frascati
  – Coordinated case studies
    • Example: Russian Heat Wave
July: Russian Heat Wave and Fires

- Central Russia ... with temperatures above 30°C for an entire month.
- “The central city of Volgograd was Russia’s hottest city with temperatures hovering above 40° Celsius (104 F) for the past few days, hotter than Cairo, Tashkent, Tehran and New Delhi.” The extreme heat is causing the former permafrost tundra to smolder and burn.
- Across Russia, “the emergencies ministry used 18 planes and 38 helicopters in an effort to douse a total of 220 wildfires, including 28 major blazes covering nearly 12,000 hectares,” a Moscow-based spokeswoman told AFP. “A major fire started in the southern Rostov region on Tuesday causing two days of explosions of World War II-era shells embedded in a local forest.”
Temperature at 2 meters

July 2011

Russian Heat Waves

July 2010

°C
Temperature at 2 meters

July 2011

July 2010

June 2003

European Heat Wave

°C
Leading Rotated EOFs
Monthly JJA V250mb

SWM response of the eddy v-wind at $\sigma=0.257$ to an idealized vorticity source at 0E, 50N

Day 20
Day 10
Day 5
Day 3
Day 1

MERRA Base State: JJA 1979-2010
V250mb REOF 1 Correlated with T2m (Monthly JJA)

July 2010 T2m Anomaly

July 2011 T2m Anomaly

1979-2005
What Forces This Wave?

At subseasonal time scales vorticity transients are the main forcing.
v250mb REOF 1 (PC, JJA 1979-2011)

Intraseasonal

Forcing by transients

Seasonal

Possible land and SST Impacts

Total

2010, 2011
July, Russian Heat Waves

2003 June European Heat Wave
Examine Impact of Land and SST on 2010 Russian Heat Wave

GEOS-5 AGCM experiments (1°):

1) initialized 1 May, 20 ensemble members, observed SST
2) initialized 1 May, 20 ensemble members, climatological SST
3) initialized 1 January, 40 ensemble members, observed SST

- Land and Atmosphere initialized from MERRA
- Anomalies wrt the mean of 4 ensemble members run for each year 1982-2000
Impact of Land/atmosphere and SST

MERRA

May

June

July

August

Impact of SST

IC (May1,2010)-Perturbation runs: 20

IC (Jan1,2010)-Perturbation runs: 40

T2m °C
T2m °C

AGCM Observed SST (IC May 1)

May 2010

June 2010

July 2010

August 2010

AGCM Climate SST (IC May 1)

Impact of Land and Atmospheric Initial conditions and land feedbacks
May 2010

AGCM Observed SST (IC May 1)

June 2010

AGCM Climate SST (IC May 1)

July 2010

August 2010

Impact of Land and Atmospheric Initial conditions and land feedbacks
Ensemble mean MERRA

13 of 20 ensemble members - initialized May 1

Ensemble mean

MERRA

July 2010 T2m

°C
2010/11 Russian Heat Waves: Preliminary Conclusions

• A summertime recurring Rossby Wave over Eurasia (forced by sub-monthly vorticity transients) gets amplified and becomes stationary

• SST anomalies appear to play a role in preconditioning (warming and drying the land)

• Land feedbacks appear to play a role in maintaining the Rossby wave
Concluding Remarks

• The GEOS-5 model is being used in a wide range of applications
  – Prediction at subseasonal to decadal time scales
  – High resolution (attribution of extremes, data assimilation)
  – Reanalysis (MERRA, working towards an IESA capability)

• GMAO will continue to contribute to MME efforts
  – APCC and new US national effort

• Invite APCC involvement in efforts to develop a GDEWS
Extra Slides
GEOS-5 AGCM for ISI Prediction

- Finite volume dynamical core (Lin, 2004)
  - 1°x1.25°x72 layers
- Convection: Relaxed Arakawa-Schubert (Moorthi and Suarez, 1992)
  - Modified after Sud and Walker (1999) to compute rainout from updraft
  - Stochastic Tokioka (1988) trigger
- Prognostic Cloud/Microphysics: Bacmeister et al. (2006)
  - Use larger of K values from the two schemes
  - Lock scheme suppressed in presence of wind shear
  - Louis turbulent length scale from (diagnosed from K profile) PBL depth
- Radiation: Shortwave – Chou and Suarez (1999), Longwave – Chou et al. (2001)
- Gravity Wave Drag Scheme based on McFarlane (1987) and Garcia and Boville (1994)
- Interactive Aerosol from GOCART model
- Chemistry
  - GHGs, ozone: relaxation to time evolving specified zonal means consistent with IPCC
The GEOS-5 OGCM for ISI Prediction

• **MOM4**
  - Version 4.1 patch 1
  - $\frac{1}{2}^\circ \times \frac{1}{2}^\circ \times 40$ levels (1/4° equatorial refinement), tri-polar grid
  - B-grid, Z-coordinate (geopotential option)
  - KPP vertical mixing
  - Laplacian horizontal diffusion and friction

• **Diurnal skin layer (Price)**

• **Sea ice: CICE (Los Alamos National Laboratory)**
ODAS-2 can be run as an Ensemble Kalman Filter (EnKF) with state-dependent multivariate background error covariances or as an Ensemble OI (EnOI) with static multivariate background error covariances

- EnKF: 20 member ensemble
- EnOI: Static ensemble of 20 EOFs from time series of differences in 20-member ensemble AOGCM simulation

T and S profiles (Buoys, XBTs, CTDs, Argo) and Reynolds SST are assimilated daily.

- XBT temperature profiles have been corrected according to Levitus et al. (2009).
- For XBTs and Buoys, synthetic salinity profiles are generated from Levitus & Boyer S(T)
- Climatological SSS is assimilated to compensate for errors in fresh water input from precipitation and river runoff.
- Sea Level Anomalies are from AVISO.
- Analysis is also constrained by Levitus & Boyer climatological temperature and salinity – correction made to first guess fields before assimilation of other real-time data – univariate.
- Multivariate covariances correct T and S, not currents.
Climatology – Annual Cycle of Daily Precipitation
V250mb Anomalies

July 2011
JUL 2011 Anomaly Climatology (5m/s contours)

July 2010
JUL 2010 Anomaly Climatology (5m/s contours)

June 2003
JUN 2003 Anomaly Climatology (5m/s contours)

m/s