Seasonal Predictions of the Anomalous Heat and Dryness during the Summer of 2012 using GFDL GCMs

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GFDL/NOAA
Princeton, NJ
USA

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U.S. Drought Monitor
CONUS

August 28, 2012
(Released Thursday, Aug. 30, 2012)
Valid 7 a.m. EST

Drought Conditions (Percent Area)

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>D0</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Last Week</td>
<td>22.72</td>
<td>14.08</td>
<td>19.16</td>
<td>21.03</td>
<td>16.70</td>
<td>6.31</td>
</tr>
<tr>
<td>5/29/2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Months Ago</td>
<td>35.98</td>
<td>26.65</td>
<td>18.43</td>
<td>13.72</td>
<td>4.57</td>
<td>0.66</td>
</tr>
<tr>
<td>5/29/2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start of</td>
<td>50.41</td>
<td>17.69</td>
<td>13.07</td>
<td>8.65</td>
<td>6.86</td>
<td>3.32</td>
</tr>
<tr>
<td>Calendar Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/3/2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start of</td>
<td>56.45</td>
<td>14.42</td>
<td>5.69</td>
<td>5.64</td>
<td>6.43</td>
<td>11.37</td>
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<tr>
<td>Water Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/27/2011</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Year Ago</td>
<td>54.07</td>
<td>13.10</td>
<td>8.09</td>
<td>6.48</td>
<td>7.06</td>
<td>11.21</td>
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<tr>
<td>8/30/2011</td>
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</tr>
</tbody>
</table>

Intensity:
- Yellow: D0 Abnormally Dry
- Light Orange: D1 Moderate Drought
- Orange: D2 Severe Drought
- Red: D3 Extreme Drought
- Brown: D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author(s):
Brian Fuchs
National Drought Mitigation Center

http://droughtmonitor.unl.edu/
GCM Development at GFDL

- **Scientific Goals:**
- Developing better models (higher resolution, improved physics) is crucial for studies of variability, predictability and forecasting on sub-seasonal to decadal time scales.
- Explore impact of atmosphere and ocean resolution on climate / climate variability
### GCM Development at GFDL

#### Scientific Goals:
- Developing better models (higher resolution, improved physics) is crucial for studies of variability, predictability and forecasting on sub-seasonal to decadal time scales.
- Explore impact of atmosphere and ocean resolution on climate / climate variability

<table>
<thead>
<tr>
<th>GCMs</th>
<th>Ocean (MOM4)</th>
<th>Atmos</th>
<th>Numerics (Atmos)</th>
<th>Computational Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM2.1</td>
<td>NA</td>
<td>250 Km</td>
<td>FV lat-lon</td>
<td>~2.5hrs/yr; ~32 PEs</td>
</tr>
<tr>
<td>AM2.5</td>
<td>NA</td>
<td>50 Km</td>
<td>Cubed Sphere</td>
<td>~4hrs/yr; ~1944 PEs</td>
</tr>
<tr>
<td>CM2.1 [NMME]</td>
<td>100 Km</td>
<td>250 Km</td>
<td>FV lat-lon</td>
<td>~2.75hrs/yr; ~64 PEs</td>
</tr>
<tr>
<td>CM2.5FLOR [NMME soon]</td>
<td>100 Km</td>
<td>50 Km</td>
<td>Cubed Sphere</td>
<td>~8.25hrs/yr; ~520 PEs</td>
</tr>
<tr>
<td>CM2.5 -&gt; CMx ?</td>
<td>Km</td>
<td>50 Km</td>
<td>Cubed Sphere</td>
<td>~5hrs/yr; ~6496 PEs</td>
</tr>
<tr>
<td>CM2.6 -&gt; CMx ?</td>
<td>4-10 Km</td>
<td>50 Km</td>
<td>Cubed Sphere</td>
<td>~12hrs/yr; ~12000 PEs</td>
</tr>
</tbody>
</table>
AM2/LM2 (Delworth et al., 2006; GFDL Global Atm. Development Team, 2004):

Lat-lon/FV Dynamical core (Lin 2004) – AM2.1,CM2.1
2.5° lon X 2.0° lat X 24 vertical levels
Cubed Sphere/FV Dynamical core (Putman and Lin, 2007) – AM2.5,CM2.5
0.5° x 0.5° x 32 vertical levels
RAS Convection (Moorthi/Suarez)
Simple cumulus momentum transport (Held)
Ramaswamy et al. radiation (rcp4.5;aerosols fixed from 2004 ->)
Prognostic cloud scheme (Klein)
UKMO PBL (Lock et al. 2000)
Stern-Pierrehumbert Orographic GWD
LM2/LM3 Land Model (Milly)

Ocean (Griffies et al., 2005):
MOM4-SIS – Ocean-Ice
GFDL Seasonal Prediction System - Overview

Tier 1

Ocean Obs
- ECDA
  - CM2.1
    - CM2.5FLOR
  - NCEP IC
  - Atmos IC
  - N. Zhang, M. J. Harrison, A. Rosati, and A. Wittenberg
    MWR 2007

Tier 2

Predicted SST
- Obs SST
- AM2.1
- AM2.5
- AM2.5 FLOR
- AMIP

Seasonal Forecast Products
- SST Forecasts

Land and moisture IC are AMIP
Season 1 tmp2m forecast

2012 JJA

CFSv1

CFSv2

ECHAM5

ECHAMA

GFSD

NCAR

NASA

NMME

Observed

North Amer. AC

CONUS AC

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Probability Forecasts

CM2.1

2012 JJA T2M Obs Anom

CM2.5 FLOR

AM2.1amip

AM2.5amip
Ensemble Forecast Probability Distributions

Tercile Forecasts - 3 category probability forecasts (above, normal, below), using historical GCM integrations to define range of anomalies.

Calculate Ranked Probability Score (RPS) and then Ranked Probability Skill Score (RPSS) following Wilks 1995 and Goddard et al., 2003, i.e.,

\[ \text{RPS} = \sum (\text{CPF}_m - \text{CPO}_m)^2 \]

where \( m = 1,3 \) and \( \text{CP} \) = cumulative probability of a category

\[ \text{RPSS} = 1 - \frac{\text{RPS}_{\text{fcst}}}{\text{RPS}_{\text{ref}}} \]

where ref = climatology
Ensemble Forecast Probability Distributions

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\[
RPS = \sum (CP_{m} - CP_{o})^2, \quad \text{where } m=1,3 \text{ and } CP = \text{cumulative probability of a category}
\]

\[
RPSS = 1 - \frac{RPS_{\text{ref}}}{RPS_{\text{ref}}}, \quad \text{where ref = climatology}
\]
Season 1 prate forecast

2012 JJA
Mid US JJA Norm Anom

Forecast Observed

Forecast Observed
Mid US JJA Anomalies

Forecast 1.465766  Observed 1.120982
Forecast 0.935278  Observed 1.09833
SESS = 1 - \sum \frac{(O_n - P_n)^2}{\sum (O_n - O)^2}

where \( n \) = time

(Jia, et al., 2014)
Normalized stdev and SESS for CM2.1 and FLOR

\[ \text{SESS} = 1 - \frac{\sum_{n}(O_n - P_n)^2}{\sum_{n}(O_n - \bar{O})^2} \]
where \( n = \text{time} \)

(Jia, et al., 2014)
Lead 1 tmp2m forecast

2014 JAN

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Summary

- GFDL GCMs predict much of the anomalous heat and dryness observed in the US during the summer of 2012 with the CM2.1 predicting extreme anomalies.

- For the central US generally JJA forecasts show a weak positive correlation with obs, but 2012 JJA forecast appears to have some real skill:
  * SSTs may contribute, but not coming from ENSO forcing
  * Observed cold SST anomalies along west coast may help maintain a trough position which might influence ridging over the center of the US.
  * Large positive 200 hPa height anomalies in May with persistent positive anomalies through July suggest a stationary wave pattern, perhaps due to phase locking of Rossby waves (see Wang et al. 2013).

- CM2.1 vs. CM2.5FLOR
  * Evidence that CM2.1 has greater variability than FLOR and observations, suggests the possibility of more extreme predictions.
  * Analysis from 30 years of hindcasts indicate that FLOR has more skill than CM2.1 for most seasons and leads.
  * Lack of observed atmospheric data in the FLOR ECDA initialization may be an issue in not being able to capture the full extent of anomalous heat and dryness during the 2012 summer.
  * Improved initialization of soil moisture might provide additional predictability.