Verification of the CPC Degree Day Outlooks

October 24, 2013

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38th Climate Diagnostics and Prediction Workshop
College Park, MD

Outline

- Summarize the CPC Population Weighted Degree Day Product.
- Present the verification of the Degree Day Product.
- Discuss how the results can be used to improve future CPC outlooks.

Degree Days - Defined

- **Degree days are a simple tool to estimate weather related energy demand.**

Definition

Mean Daily Temperature = t = .5*(Tmax+Tmin)

Heating is needed when t < 65 F

Cooling is needed when the t > 65 F.

Costs are approximately linearly related to degree days.

Degree Days Vs. Gas Consumption

Reference: Relations between Temperature and Residential Natural Gas Consumption in the Central and Eastern U.S.

Journal of Applied Meteorology and Climatology, November, 2007 Authors. Reed Timmer and Peter J. Lamb

Results: Correlation with HDD is higher in the north(r=.9) than south (r=.6).

Optimum HDD base is lower than 65F in the north, somewhat higher in the south.

Other Elements: Wind – Not well predict at long ranges.
Sunshine/ clouds – Already reflected in the temperatures

Humidity – More important for cooling than heating. Year-to-year variations not being predicted

Definitions

$$HDD = \Sigma(65 - \bar{t}) \quad t \leq 65$$

$$CDD = \Sigma(\bar{t} - 65) \quad t > 65$$

$$HD = \frac{HDD}{N} \qquad CD = \frac{CDD}{N}$$

T = 65+CD-HD

CD = T –65 +HD

t = daily mean temperature, T=Monthly or Seasonal Mean

N = Number of days in month or season

Degree Day Outlook

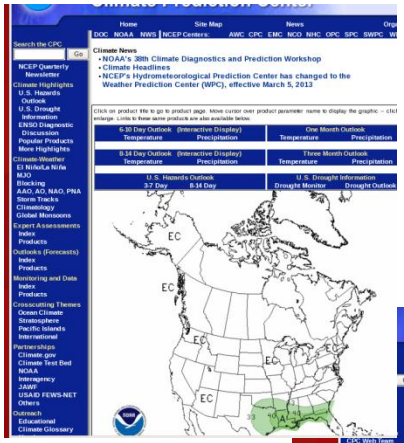
- Based on the CPC Temperature Outlook
- Mean relationship between monthly or seasonal temperature, and degree days.
- Downscaled and disaggregated from 3-mo seasons on CPC forecast divisions to monthly on NCDC climate divisions and individual months
- Aggregated onto political boundaries – population weighted.

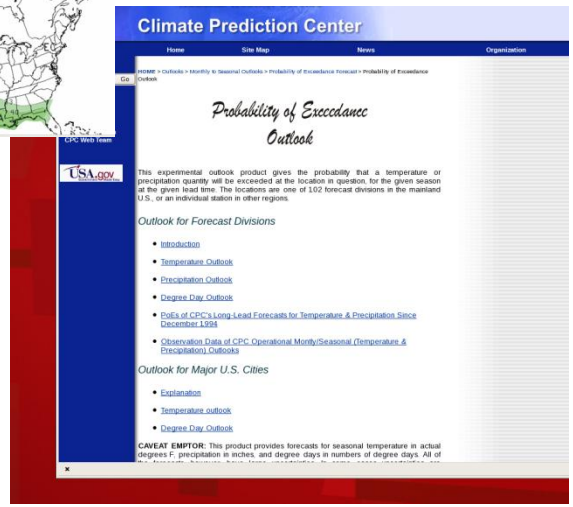
  Population weighing reflects energy demand.

Seasonal Products

http://www.cpc.ncep.noaa.gov/pacdir/DDdir/NHOME3.shtml

- CPC Seasonal Outlooks – States, Regions.
- Issued on the third Thursday of each month.





Inbox (17) - david.unger@no... | CF : RFC Main Search Page | http://www.ftp...egress.cdcoeff | http://www.cpc...ddforecast.txt

www.cpc.ncep.noaa.gov/pacdir/DDdir/ddforecast.txt

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EXPERIMENTAL MONTHLY TOTAL DEGREE DAY FORECAST
BASE 65 F
NWS CLIMATE PREDICTION CENTER  CAMP SPRINGS MD
300 PM EST THU 20 MAR 2013

NEW ENGLAND          (CT ME MA NH RI VT)                          NORMALS       FORECAST
                        HEATING                  COOLING          (1981-2010)   DEPARTURE
YEAR MONTH   90%    MEAN    10%      90%    MEAN    10%      HDD    CDD    HDD    CDD
2013    4   481.    551.    630.      0.      0.      0.      583.     0.   -32.     0.
2013    5   187.    253.    320.      2.      9.     19.      281.     6.   -28.     3.
2013    6    34.     56.     85.     38.     73.    112.       66.    63.   -10.    10.
2013    7     2.      9.     15.    146.    194.    246.       11.   180.    -2.    14.
2013    8    10.     22.     34.    114.    157.    204.       26.   146.    -4.    11.
2013    9   100.    140.    175.     12.     26.     55.      153.    22.   -13.     4.
2013   10   359.    445.    533.      0.      0.      2.      467.     0.   -22.     0.
2013   11   587.    705.    807.      0.      0.      0.      727.     0.   -22.     0.
2013   12   894.   1049.   1213.      0.      0.      0.     1078.     0.   -29.     0.
2014    1  1051.   1218.   1433.      0.      0.      0.     1246.     0.   -28.     0.
2014    2   877.   1032.   1185.      0.      0.      0.     1060.     0.   -28.     0.
2014    3   783.    886.    991.      0.      0.      0.      913.     0.   -27.     0.
2014    4   491.    566.    650.      0.      0.      0.      583.     0.   -17.     0.
2014    5   197.    268.    341.      1.      8.     17.      281.     6.   -13.     2.
2014    6    39.     65.     99.     30.     64.    101.       66.    63.    -1.     1.

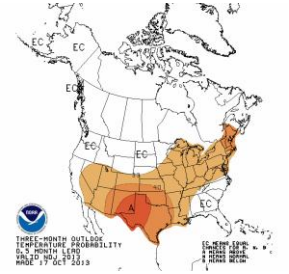

MID ATLANTIC         (NJ NY PA)                                   NORMALS       FORECAST
                        HEATING                  COOLING          (1981-2010)   DEPARTURE
YEAR MONTH   90%    MEAN    10%      90%    MEAN    10%      HDD    CDD    HDD    CDD
2013    4   393.    468.    542.      0.      0.      0.      496.     0.   -28.     0.
2013    5   123.    191.    252.     12.     30.     55.      217.    23.   -26.     7.
2013    6    17.     33.     58.     77.    130.    179.       39.   117.    -6.    13.
2013    7     2.      4.     10.    198.    261.    321.        6.   247.    -2.    14.
2013    8     5.     14.     22.    160.    216.    276.       16.   205.    -2.    11.
2013    9    67.     97.    128.     41.     65.     97.      105.    59.    -8.     6.
2013   10   274.    382.    485.      0.      6.     15.      399.     5.   -17.     1.
2013   11   540.    653.    766.      0.      0.      0.      667.     0.   -14.     0.
2013   12   829.    981.   1158.      0.      0.      0.      998.     0.   -17.     0.
2014    1   965.   1141.   1351.      0.      0.      0.     1158.     0.   -17.     0.
2014    2   804.    960.   1093.      0.      0.      0.      983.     0.   -23.     0.
2014    3   691.    801.    915.      0.      0.      0.      827.     0.   -26.     0.
2014    4   400.    478.    557.      0.      0.      0.      496.     0.   -18.     0.
2014    5   130.    202.    268.      9.     27.     52.      217.    23.   -15.     4.
2014    6    19.     37.     66.     67.    120.    169.       39.   117.    -2.     3.
```

Overview

Tools

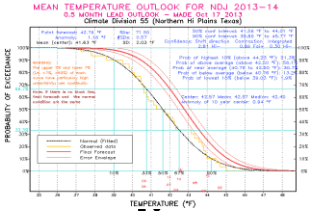
Forecaster Input

Temperature Fcst
Prob. Anom.For Tercile
(Above, Near, Below)



Model Skill, climatology

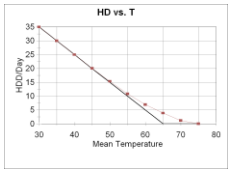
Temperature POE



Downscaling (Regression Relationships)

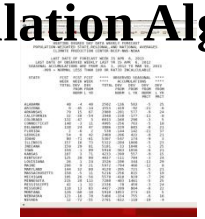
Temperature POE
Downscaled, Disaggregated

Temperature to Degree Day
(Climatological Relationships)



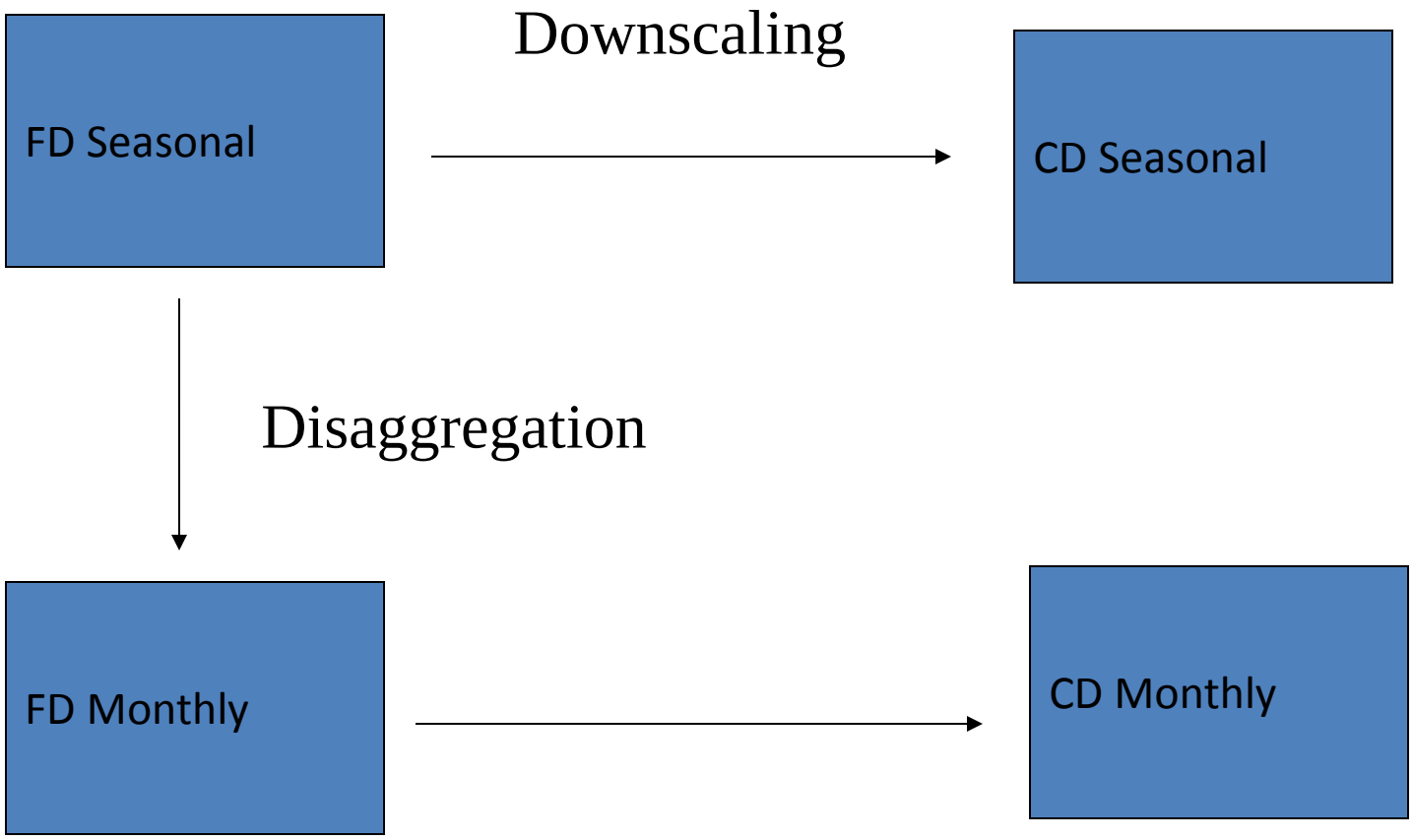
Degree Days
HDD CDD POE

Accumulation Algorithms



Degree Days
Flexible Regions, Seasons

Rescaling


FD Seasonal
Downscaling
CD Seasonal
Disaggregation
FD Monthly
CD Monthly

Downscaling

- Regression
- CD = a FD +b

  Equation's coefficients are "inflated"

  (CD variance = climatological variance)

Disaggregation - Seasonal to Monthly

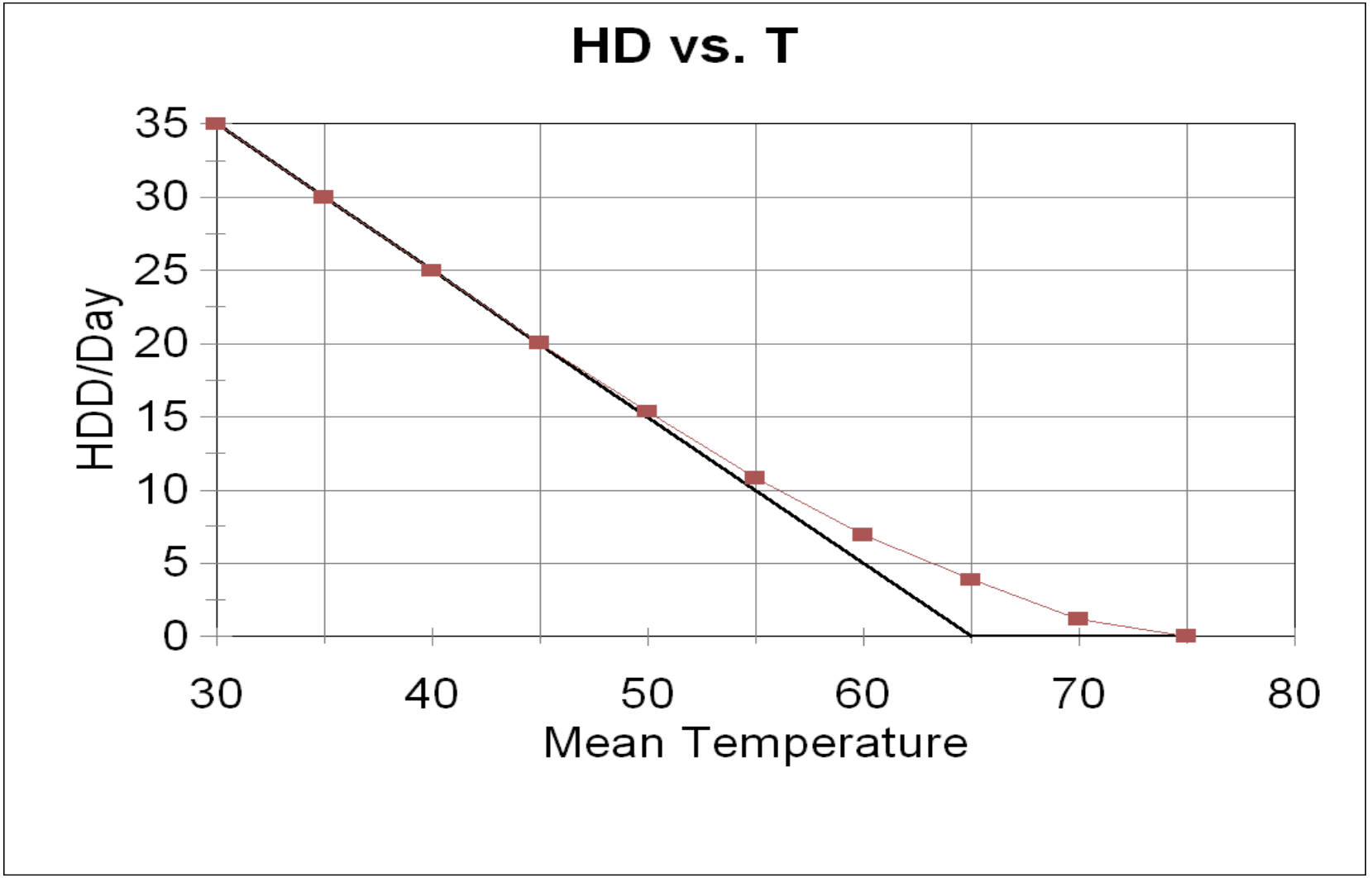
- Tm = a Ts + b

  Regression, inflated coefficients

- Average 3 estimates

$$M = \frac{M \leftarrow JFM + M \leftarrow FMA + M \leftarrow MAM}{3}$$

Temperature to Degree Days



Accumulation Algorithm

Mean values are simple sums

$$\overline{DD}_{A+B} = \overline{DD}_A + \overline{DD}_B$$

Standard deviations depend on the covariance
At one extreme, totally independence yields

$$\boldsymbol{\sigma_{A+B} = \sqrt{\sigma_A{}^2 + \sigma_B{}^2}}$$

For totally dependent data

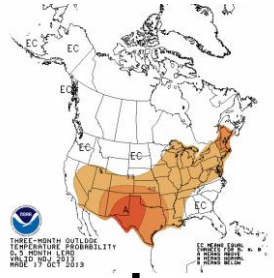
$$\boldsymbol{\sigma_{A+B} = \sigma_A + \sigma_B}$$

Given the climatology $\boldsymbol{\sigma_{(C)A+B}}$

$$\boldsymbol{\sigma_{(I)A+B} \leq \sigma_{(C)A+B} \leq \sigma_{(D)A+B}}$$

$$\boldsymbol{R = \frac{\sigma_{(C)} - \sigma_{(I)}}{\sigma_{(D)} - \sigma_{(I)}}} \qquad \boldsymbol{\sigma_{A+B} = \sigma_{(I)} + R(\sigma_{(D)} - \sigma_{(I)})}$$

Calibration



30-yr WMO Climatology

Make POE, Downscale, Apply TT to DD relationship

Make POE, Downscale, Apply TT to DD relationship

DD Anomaly = DD (CPC Forecast) – DD(30-year Climo)

Final forecast = NCDC Mean + Anomaly

Data

Forecasts

- Official CPC forecasts Initial times Jan, 1995 – Dec 2011
- Stratified by Lead times (months)
- Stratified by TARGET Months in Winter (DJF), Spring(MAM), Summer (JJA) or Fall (SON)
- Heating season totals N D J F M A , Lead 1 = Forecast issued in October
- Cooling season Totals M J J A S Lead 1 = Forecast issued In April

Scores

Mean Absolute Error (ABS(Forecast – OBS)
Credible interval score based on the CRPS
Bias = Forecast – Observation

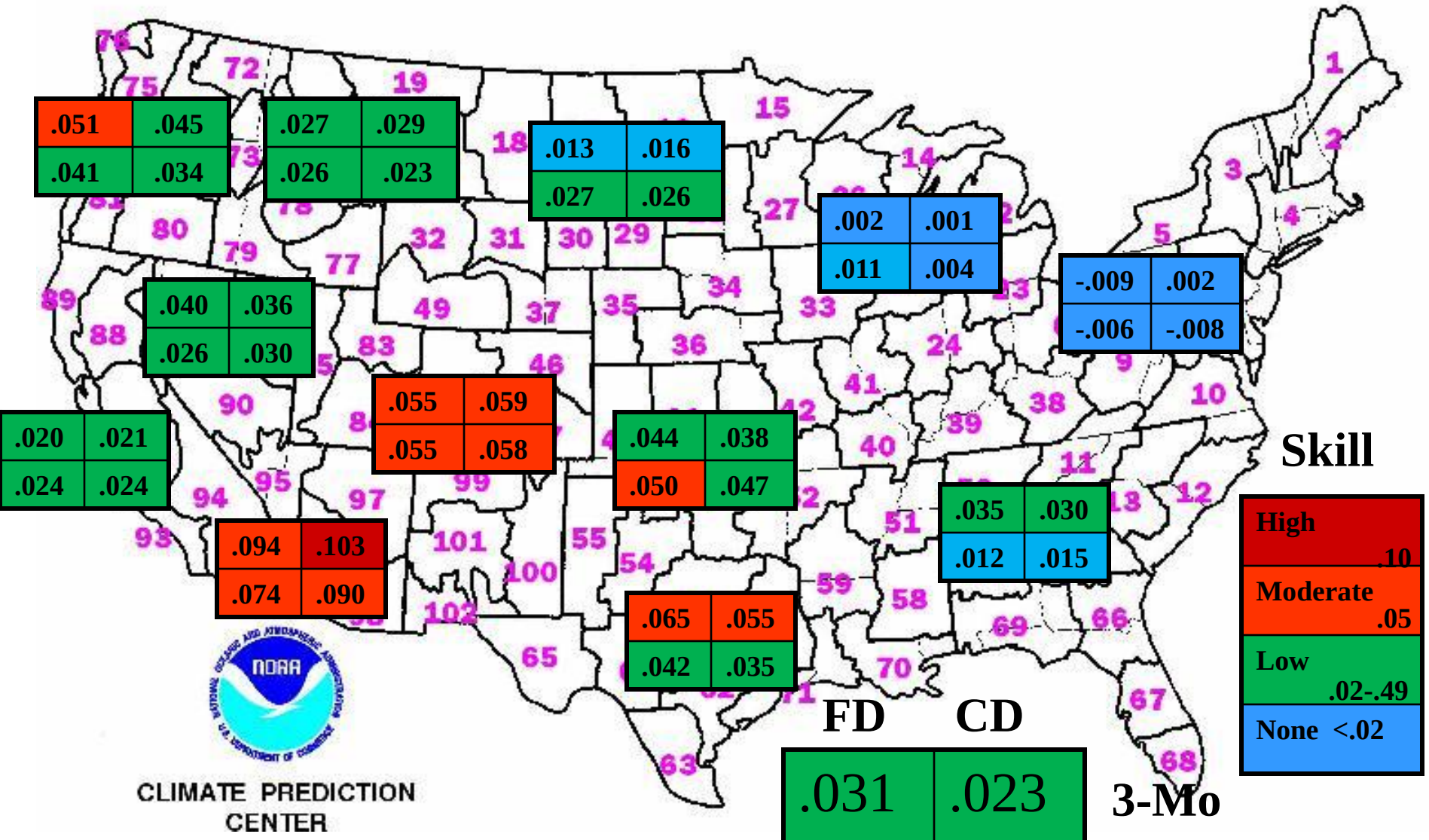
Observations

NCDC Population Weighted degree days for states and groups of states, and nationwide based on 2000 census.

Caution: Only a 17-year sample.

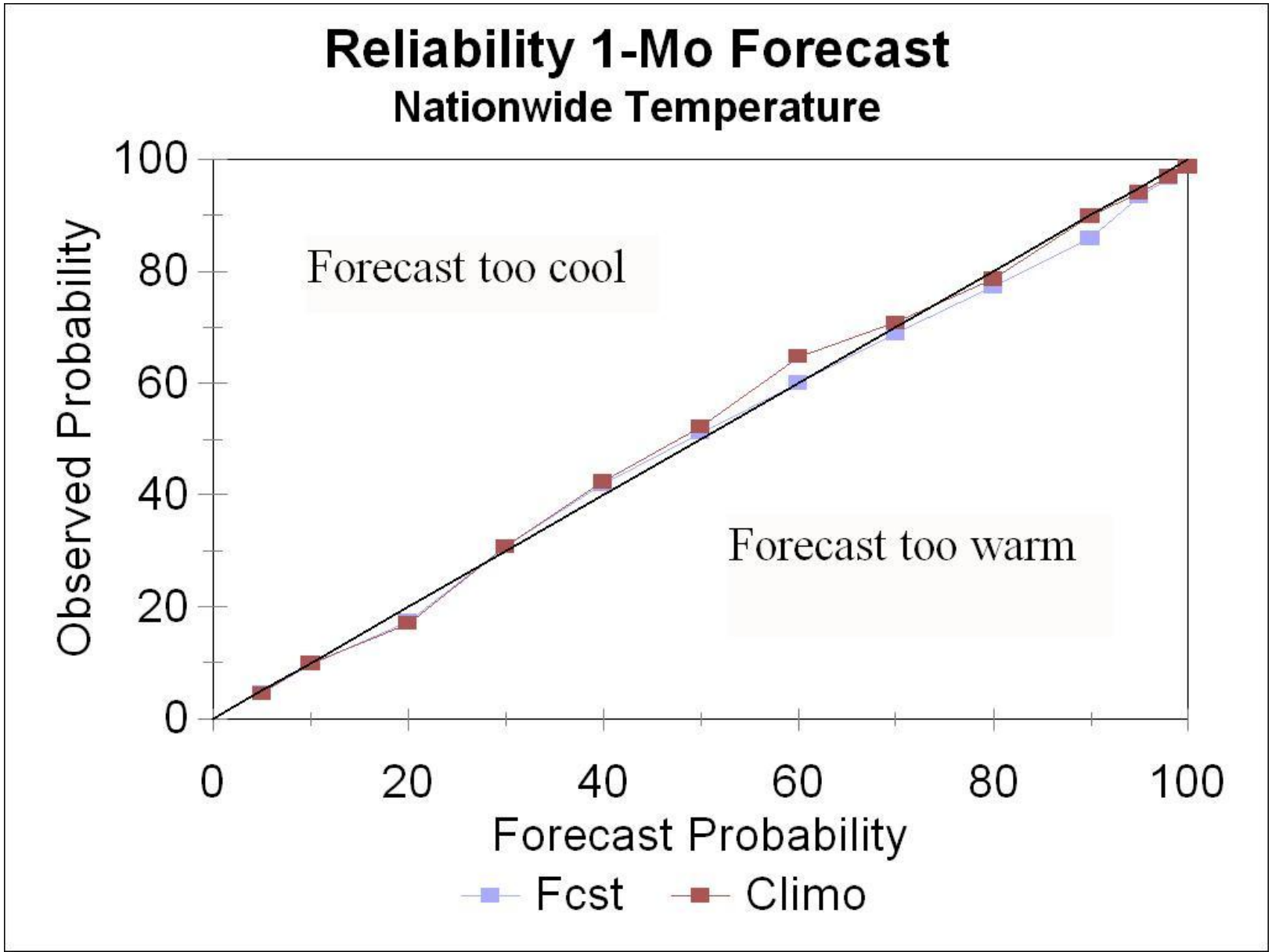
VERIFICATION
PART 1 INTERMEDIATE STAGES
(BASED ON FULL DISTRIBUTIONS ON CLIMATE DIVISIONS)

CRPS Skill Scores: Temperature

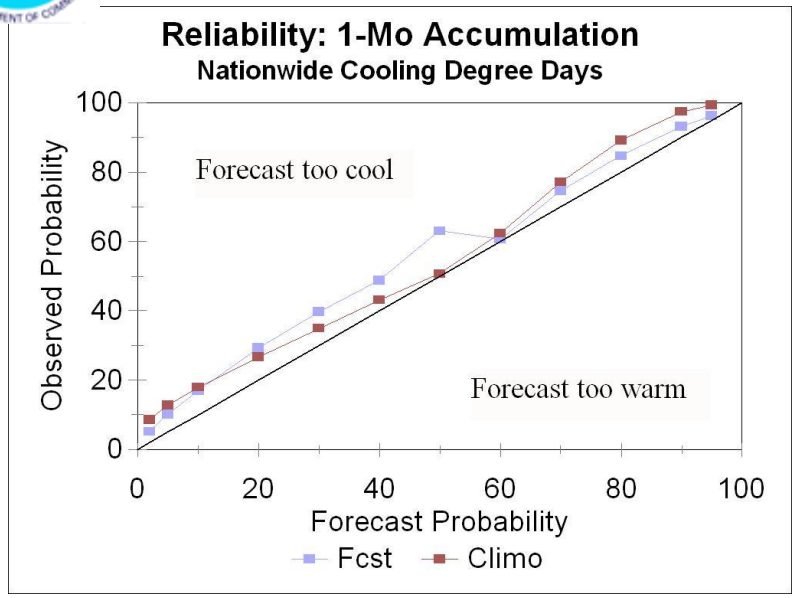


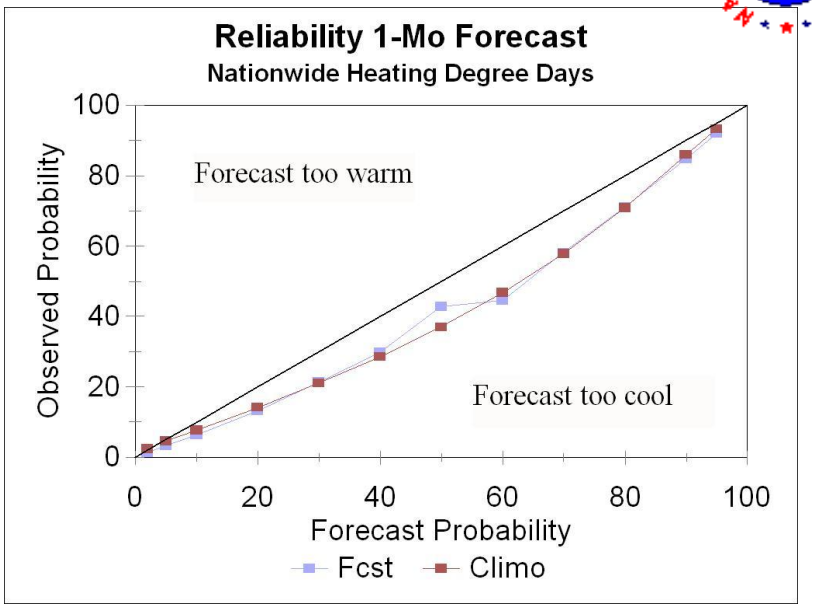
1-Month Lead, All initial times

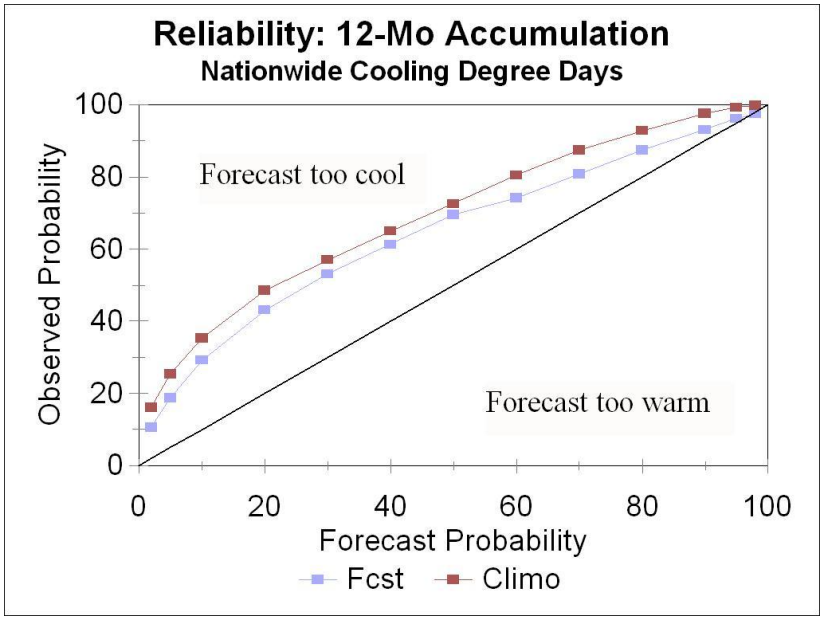
Reliability

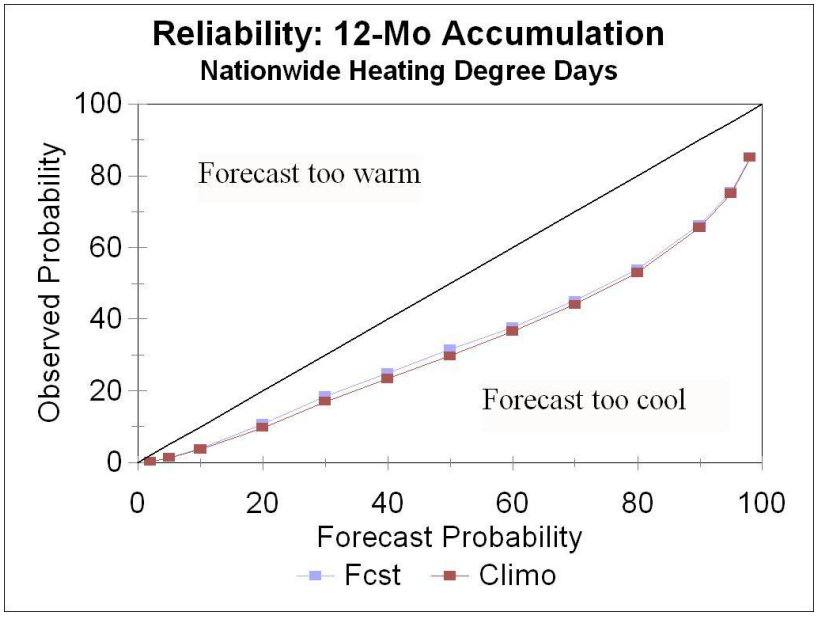


Reliability



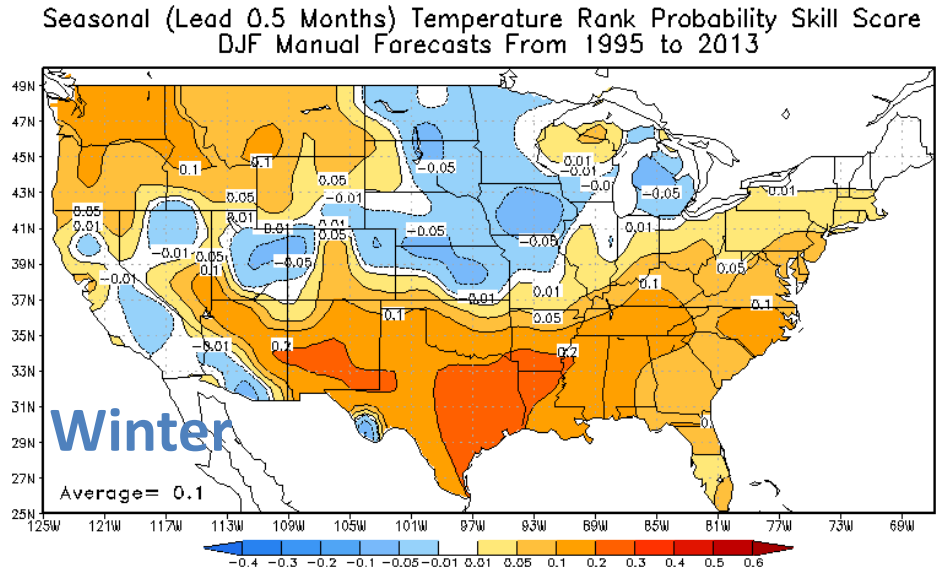


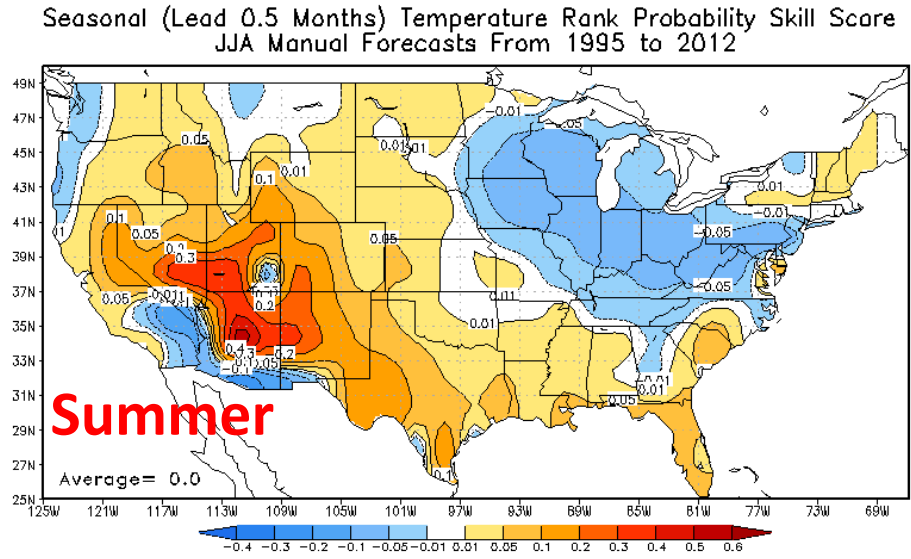


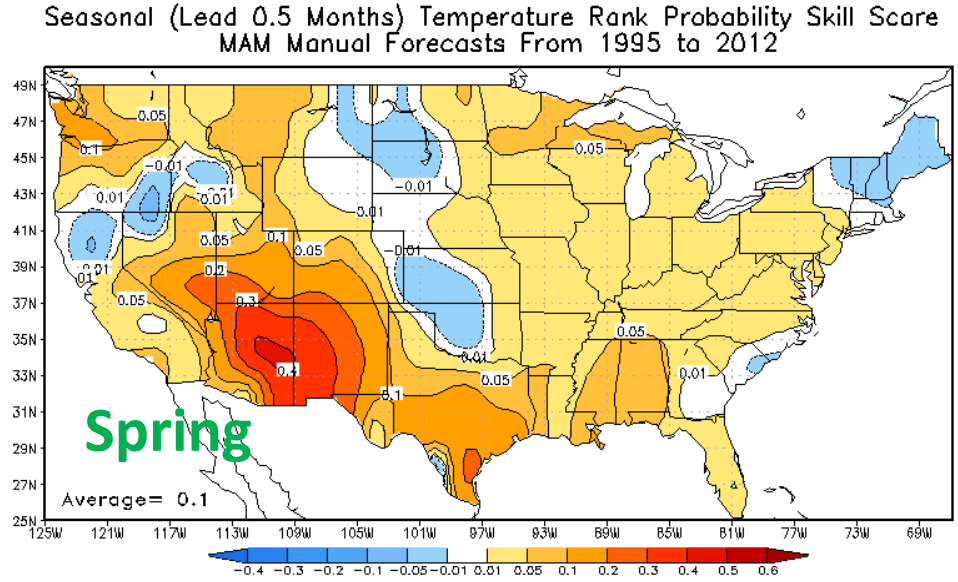


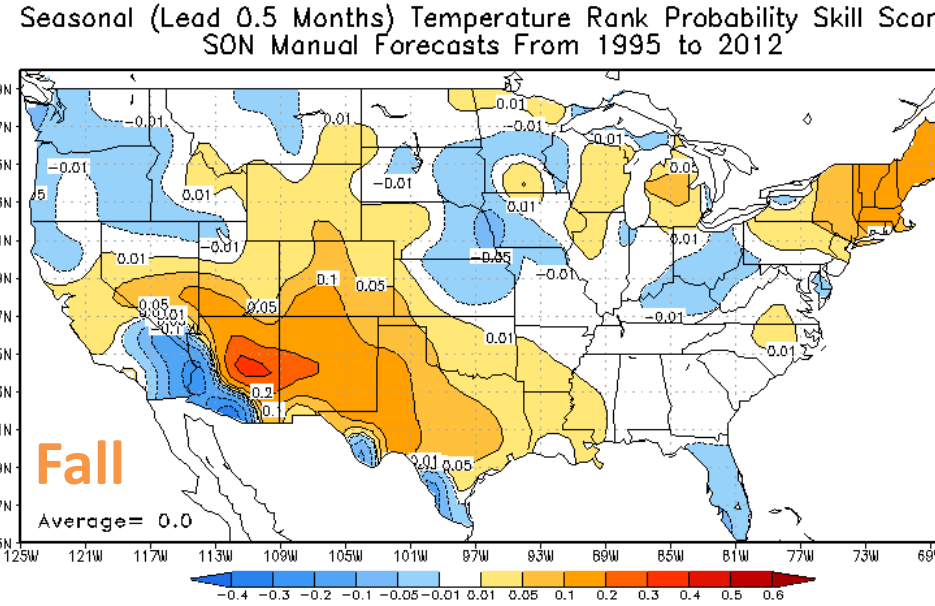
VERIFICATION
PART 2 POPULATION WEIGHTED PRODUCT

Skill of CPC Temperature Outlooks

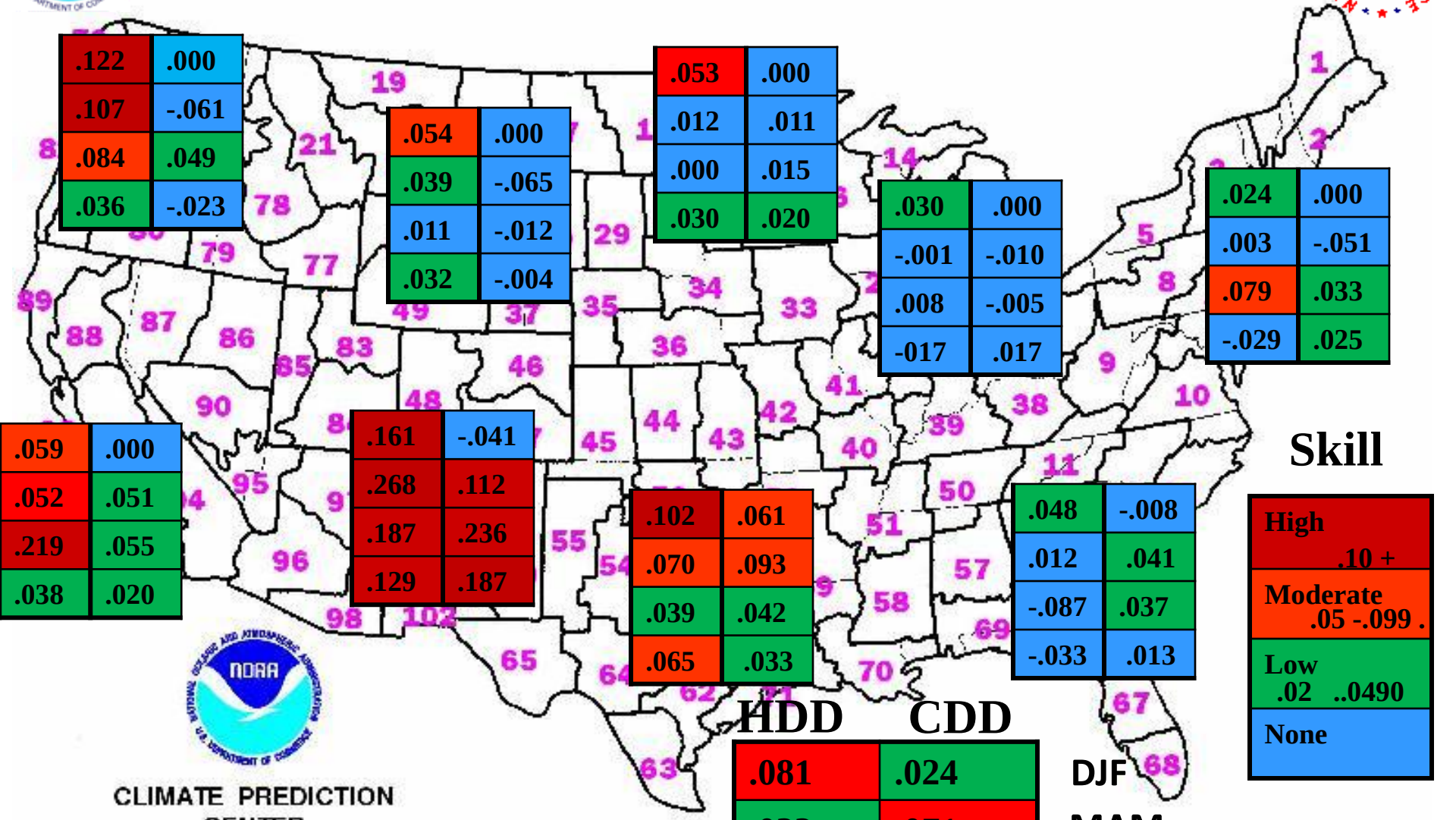




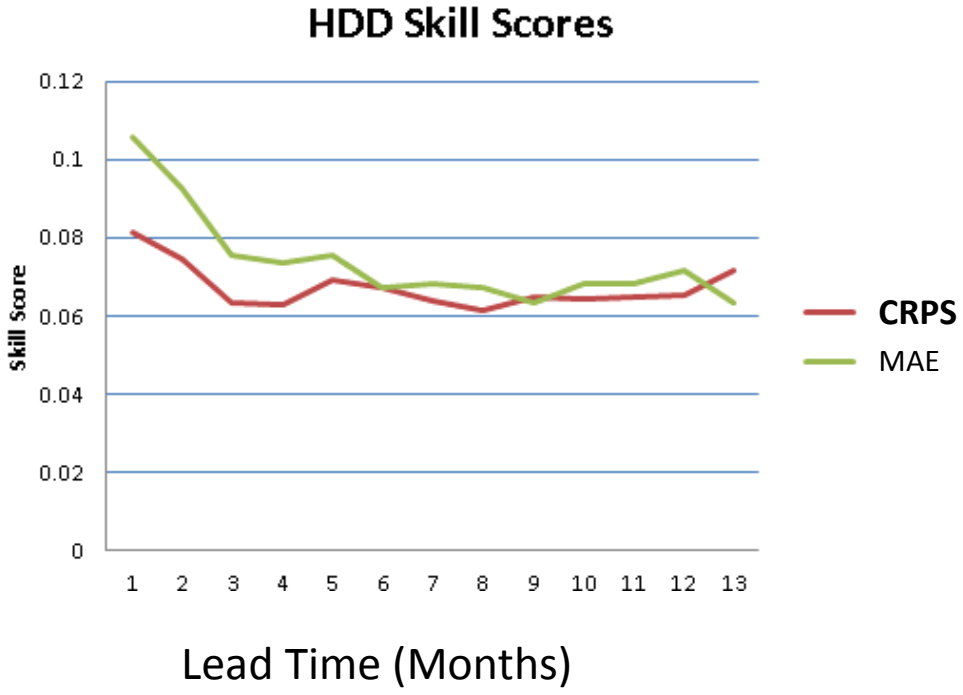




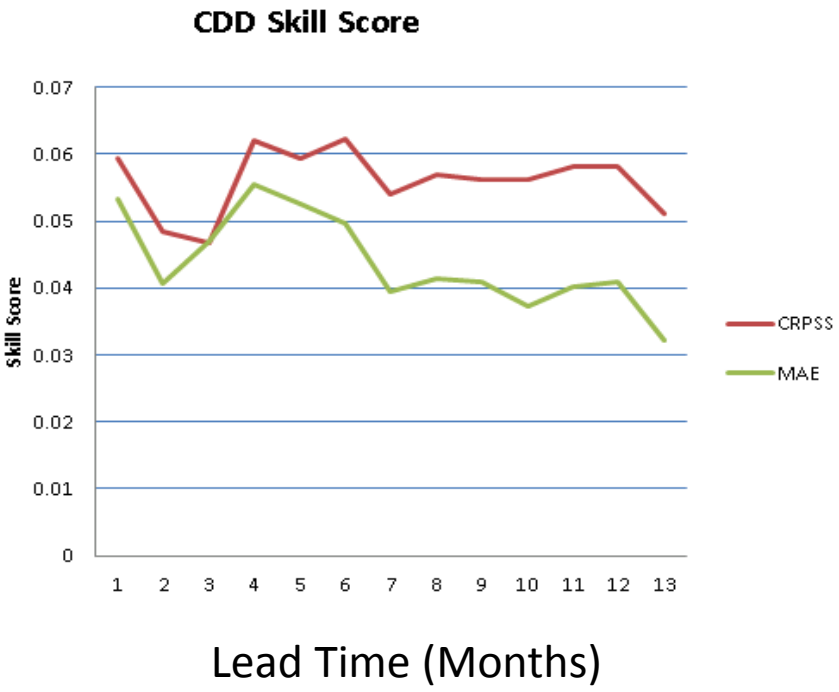
CRPS Skill Scores: Heating and Cooling Degree Days



CRPS and MAE Skill Scores Lead 1

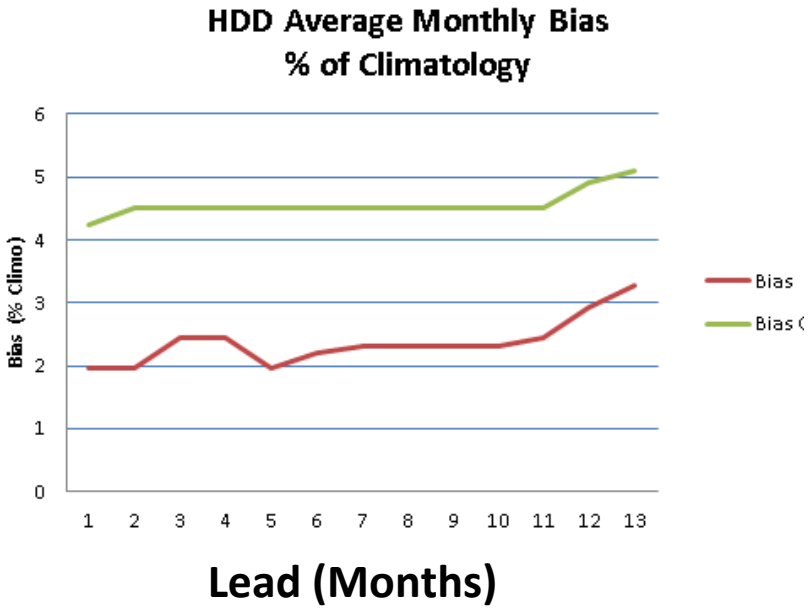


Winter (DJF) Target

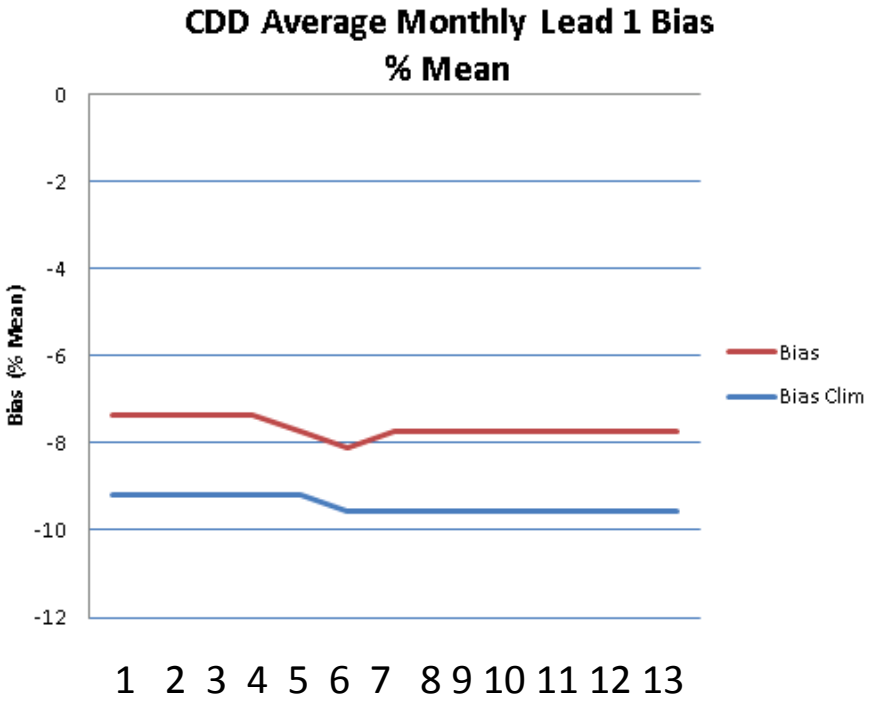


Summer (JJA) Target

Average Monthly Bias (% Climo) Lead 1



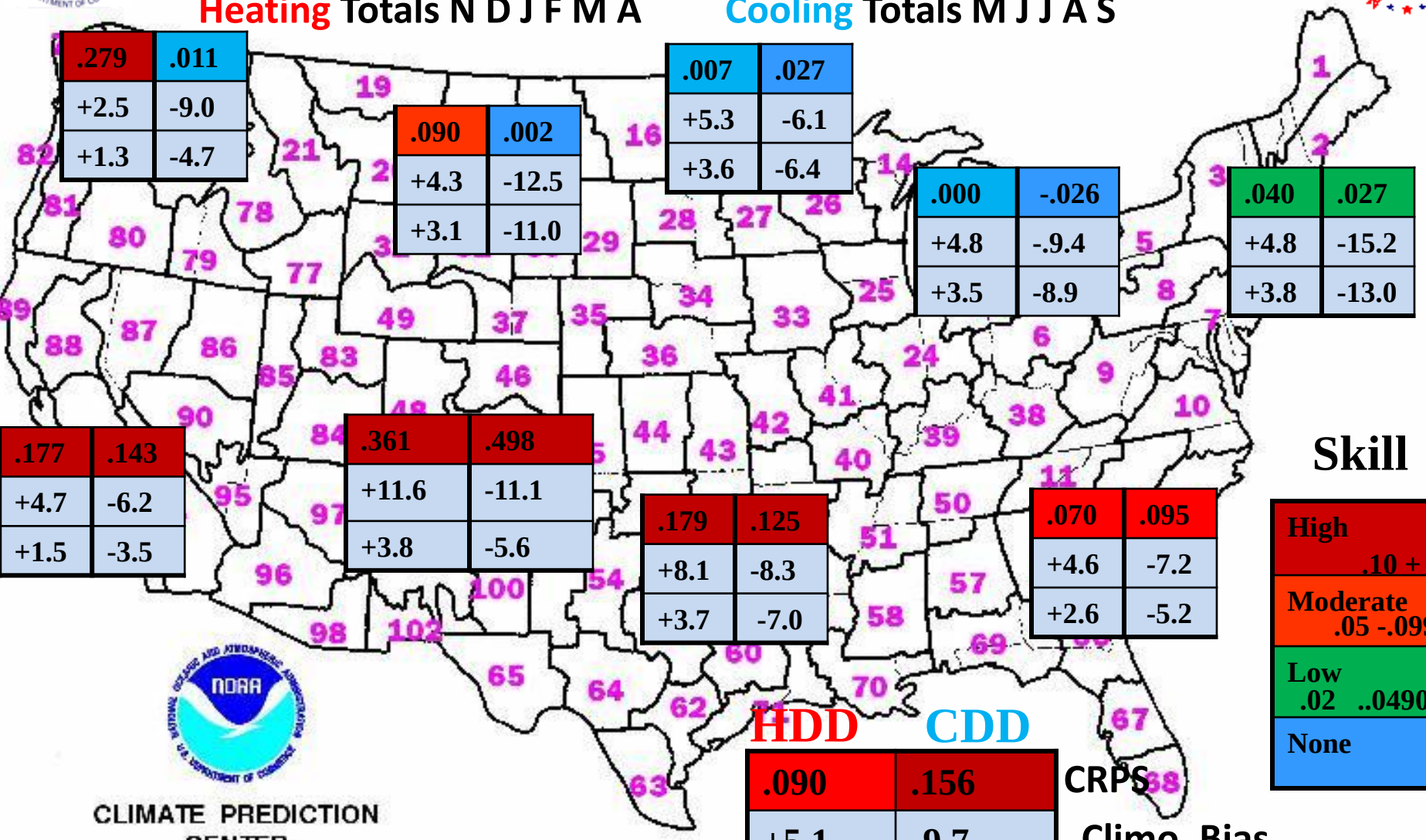
Winter (DJF) Target



Summer (JJA) Target

CRPS Skill Scores: Heating and Cooling Degree Days

Heating Totals N D J F M A **Cooling** Totals M J J A S



Skill

High .10 +
Moderate .05 -.099 .
Low .02 ..0490
None

HDD	CDD	
.090	.156	CRPS
+5.1	-9.7	Climo. Bias
+3.3	-7.7	Fcst. Bias

CLIMATE PREDICTION CENTER

Lead 1 Seasonal Total

1995 - 2011

Correcting Bias

Tests

1) **OCN-15 is the overall best (Optimum Climate Normal) Apply this to the "EC" areas.**

Apply OCN-15 where the anomaly is the same sign as the CPC forecast and where OCN 15 is more anomalous than the CPC forecast.

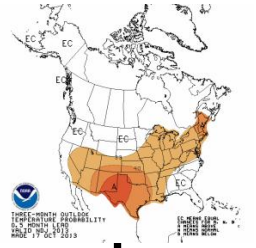
2) Do the same except use an Updating 30-year normal.

Example:

Use the 1975-2004 normal for outlooks issued in 2005.

Compare these to the 1971-2000 "Official" WMO base period.

Calibration



Alternative Normals

30-yr WMO Climatology

Make POE

Make POE

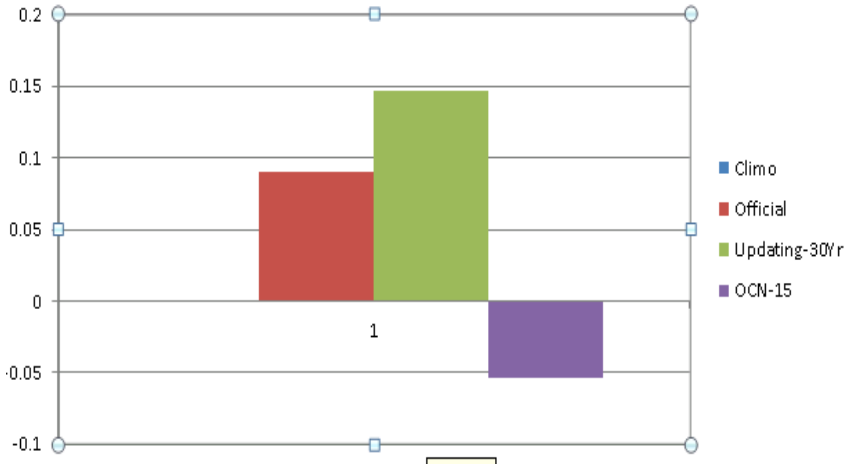
Make POE

Replace POE from "EC" forecasts with POE from alternative normals
Replace weak CPC forecasts with stronger same-sign alternative normals

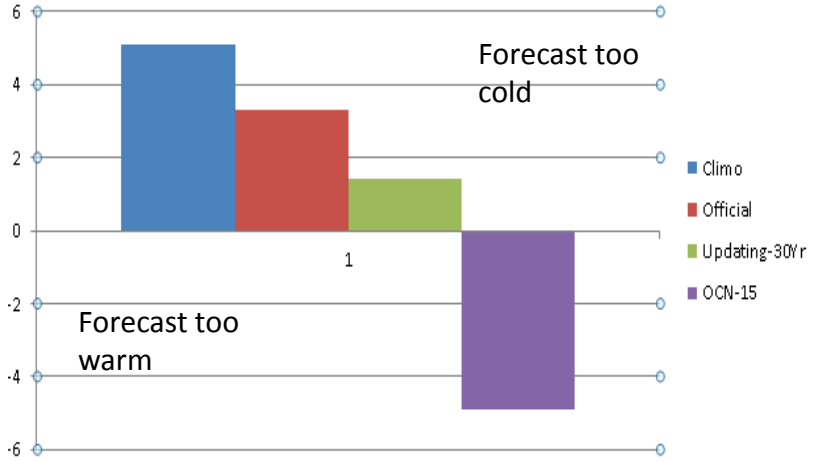
Downscale, Apply TT to DD relationship

DD Anomaly =Revised CPC Forecast – 30-year Climo
Final Forecast = NCDC Mean + Anomaly

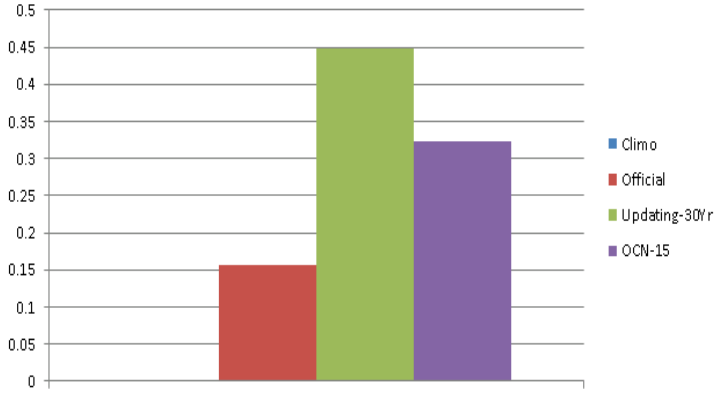
Nationwide Heating Degree Days Seasonal Totals, Lead 1



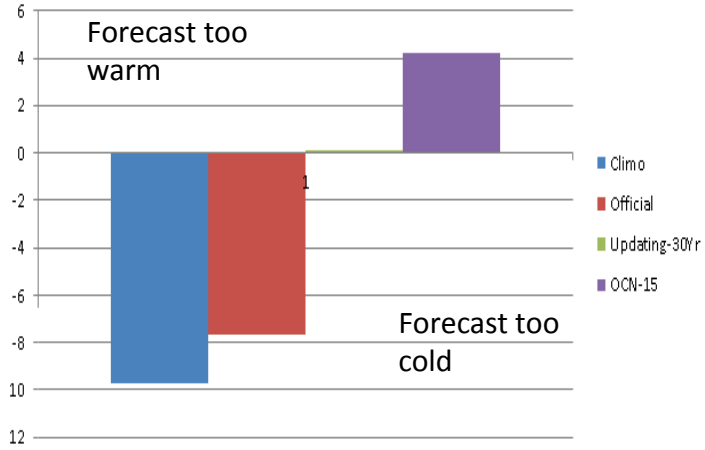
Climo Official 30-yr Updt OCN-15



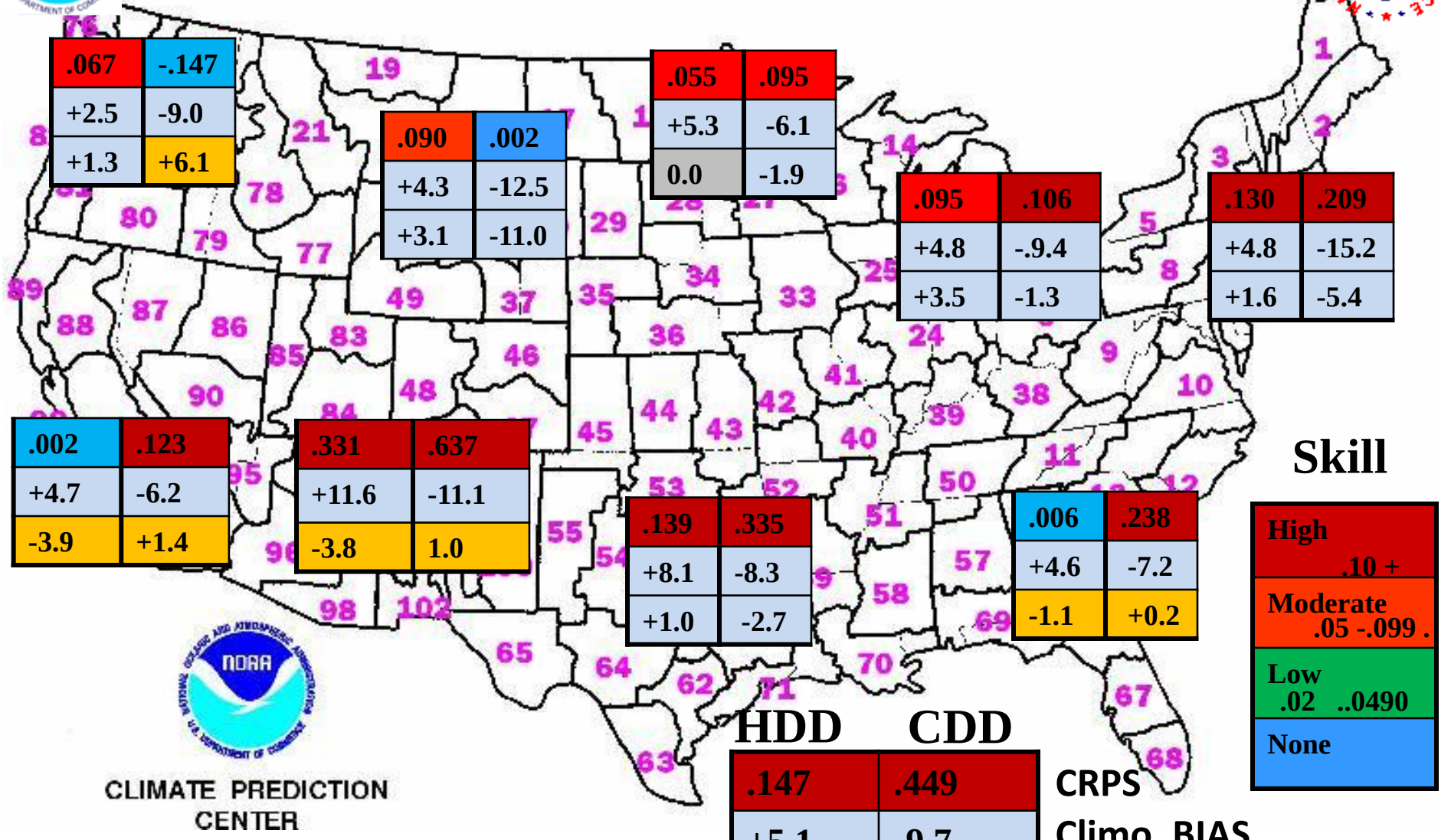
Nationwide Cooling Degree Days Seasonal Totals, Lead 1



Climo Official 30-yr Updt OCN-15



CRPS Skill Scores: Heating and Cooling Degree Days



CLIMATE PREDICTION CENTER

Lead 1 Seasonal Total

Updating Normals

Summary and Recommendation

- Degree Day Outlooks about as skillful as CPC Temperature Outlooks
- Seasonal Totals usually are somewhat more skillful than monthly values
- Systematic cold bias
  - 3% in for Heating Degree Days
  - 8% for Cooling Degree Days
- Bias is due to the failure of the forecasters to properly account for aging normals. (Base period fixed by decade)
- Forecasters are likely properly applying OCN. OCN-based Degree Day bias correction degrades skill.

Recommendation:

CPC forecasts should be quantitatively revised to account for aging normals.

(Or use updating 30-year normals as a climatological base period)