Seasonal Climate Prediction at Climate Prediction Center
CPC/NCEP/NWS/NOAA/DoC

Huug van den Dool
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Menu of CPC predictions:

- 6-10 day (daily)
- Week 2 (daily)
- Monthly (monthly + update)
- **Seasonal** (monthly)
- Other (hazards, drought monitor, drought outlook, MJO, UV-index, degree days, POE, SST) (some are ‘briefings’)
- Informal forecast *tools* (too many to list)

Climate??

By example:

A *weather* forecast: Rain in the morning, sun in the afternoon. High in mid-fifties

A *climate* forecast: Temp in DJF 2009/10 will be in upper tercile with a 48% probability
Each month, on the Thursday between the 15th and 21st, CPC, on behalf of NWS, issues a set of 13 seasonal outlooks.

There are two maps for each of the 13 leads, one for temperature and one for precipitation for a total of 26 maps.

Each outlook covers a 3-month “season”, and each forecast overlaps the next and prior season by 2 months.

Bulletins include: the prognostic map discussion (PMD) for the seasonal outlook over North America, and, for Hawaii.

The monthly outlook is issued at the same time as the seasonal outlook. It consists of a temperature and precipitation outlook for a single lead, 0.5 months, and the monthly PMD.

All maps are sent to AWIPS, Family of Services and internet.

‘Official’ SST forecasts
Issued:
Apr 17
2008
Issued:
Mar 17
2007
Fig. 9.2 A lay-out of the seasonal forecast, showing the averaging time, and the lead time (in red). Rolling seasonal means at leads of 2 weeks to 12.5 months leads are being forecast.
Distinguish 3 time scales:

1) Averaging time
2) Lead time
3) Time scale of physical process we try to predict

Examples of 3rd point:
- ENSO (a few years)
- Inter-decadal (no name, trend, global change)

Reflect on definition of time scale.
What is time scale of seasonal forecast? Fourier
<table>
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<tr>
<th></th>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>OCN</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Constructed Analog</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Markov</td>
<td>X</td>
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<tr>
<td>ENSO Composite</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (GCM) models (IRI, ECHAM, NCAR, CDC etc):</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>Cane&amp;Zebiak</td>
<td>X</td>
<td></td>
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<td>Multiple Lin Reg</td>
<td>X</td>
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<td>Consolidation</td>
<td>X</td>
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<td>X</td>
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</table>

CCA = Canonical Correlation Analysis
OCN = Optimal Climate Normals
CFS = Climate Forecast System (Coupled Ocean-Atmosphere Model)
JFM Season:  All-Stns: +9.7 / Non-EC: +10.8 / %-Covg: 89.8
JFM Season [Temperature]  
{ALL: +10.1 / NON-EC: +16.6 / %-COVG: 61.2}
Coupled Forecast System at NCEP

History:

• MRF-b9x, CMP12/14 1995 onward (Leetmaa, Ji, etc
• SFM 2000 onward (Kanamitsu et al
• CFS, the 1st truly coupled global system at NCEP (aug 2004)
• Next CFS: Jan 2010


All CFS info is at http://cfs.ncep.noaa.gov/
Long Lead Predictions of US Surface Temperature using *Canonical Correlation Analysis*. Barnston (J. Climate, 1994, 1513)

Predictor - Predictand Configuration

**Predictors** | **Predictand**
--- | ---
* Near-global SSTA
* N.H. 700mb Z | * US sfc T
* US sfc T

four predictor “stacked” fields       one predictand period

4X652=2608 predictors       102 locations

Data Period 1955 - last month
Fig. 3. Schematic of the timing of the predictor and predictand periods for the five lead times used in the study, for the example of forecasting Dec-Jan-Feb 1993/94. Each row illustrates a progressively larger lead time, with the four predictor periods (numbered beneath the month abbreviations) retreating farther into the past with increasing lead. The lead period is represented by lowercase month abbreviations with dots above them. A similar diagram could be drawn for other target seasons, or for fixed predictor periods and a variable target period as in real-time forecasting using the most recent 12 months of predictor data.
Fig. 6. CCA forecast skill averaged over the United States for 3-month mean temperature (as in Fig. 4a) except the SST field is weighted double its natural value.
About *OCN*. Two contrasting views:
- Climate = average weather in the past
- Climate is the ‘expectation’ of the future


*OCN* = Optimal Climate Normals: Last K year average. All seasons/locations pooled: K=10 is optimal (for US T).

Forecast for Jan 2010

\[ \text{Forecast} = \frac{\text{Jan00+Jan01+... Jan09}}{10}. \]

– WMO-normal plus a skill evaluation for some 50 years.

Why does OCN work?
1) climate is not constant (K would be infinity for constant climate)
2) recent averages are better
3) somewhat shorter averages are better (for T)
   → see Huang et al 1996. J.Climate. 9, 809-817.
NCEP’s old (Two-Tier) Coupled Model Forecast

INTEGRATED OCEAN MODEL- DATA ASSIMILATION SYSTEM

OCEAN INITIAL CONDITIONS

COUPLED OCEAN- ATMOSPHERE GCM

AGCM FORECASTS

STRESS

EVAP-PRECIP FLUX

HEAT FLUXES

SSTA

STRESS

EVAP-PRECIP FLUX

HEAT FLUXES

STATISTICAL TOOLS: CCA, CA, MRK

FORECASTERS

OFFICIAL SST FCST

SURFACE T, P ANOMALIES

FORECASTERS

OFFICIAL PROBABILISTIC T,P OUTLOOKS

STRESS

EVAP-PRECIP FLUX

HEAT FLUXES

STATISTICAL TOOLS: CCA, CA, MRK

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OFFICIAL PROBABILISTIC T,P OUTLOOKS
NCEP (One-Tier) Coupled Model Forecast

INTEGRATED OCEAN MODEL-DATA ASSIMILATION SYSTEM

- SST
- TOPEX
- XBT
- TAO

- STRESS
- EVAP-PRECIP FLUX
- HEAT FLUXES

OCEAN & ATMOSPHERE &LAND INITIAL CONDITIONS

COUPLED OCEAN-ATMOSPHERE GCM

SSTA

STATISTICAL TOOLS: CCA, CA, MRK

IRI,CDC

SURFACE T, P ANOMALIES

FORECASTERS

OFFICIAL SST FCST

FORECASTERS

OFFICIAL PROBABILISTIC T,P OUTLOOKS
Major Verification Issues

• ‘a-priori’ verification (used to be rare)
• After the fact (fairly normal)
(Seasonal) Forecasts are useless unless accompanied by a reliable a-priori skill estimate.

Solution: develop a 50+ year track record for each tool. 1950-present.

(Admittedly we need 5000 years)
Fig. 6. CCA forecast skill averaged over the United States for 3-month mean temperature (as in Fig. 4a) except the SST field is weighted double its natural value.
Heidke Score (SS): 
(H-E)/(T-E) 
2* SS~ = correlation
Fig. 9 Spatial distribution of retrospective (1981-2003) forecast skill (anomaly correlation in %) over the United States for lead 1 seasonal mean JJA temperature (left panel) and DJF temperature (right panel).

From top to bottom, the number of members in the CFS ensemble mean increases from 5 to 15. Values less than 0.3 (deemed insignificant) are not shown. The period is 1981-2003

1981-2003 (now 2006) is not much! if 5000 years is needed. Main limitation: ocean analysis
As in Fig. 9, but now for Precipitation.
Fig. 11 Left column: Spatial distribution of retrospective ensemble mean CFS forecast skill (anomaly correlation in %) for lead 1 seasonal mean temperature over the United States. The target seasons are, from top to bottom, MAM, JJA, SON and DJF. The CFS (left) is compared to CCA, in the right column. Note that CCA is based on a longer period, 1948-2003. Correlation less than 0.3 are not shown.
As in Fig. 11, but now for precipitation.
Hindcast skill of US temperature by SFM for February ICs

1-month lead

2-month lead

3-month lead

4-month lead

[Color scale for temperature skill values: 0.3, 0.4, 0.5, 0.6, 0.7, 0.8]
OFFicial Forecast(element, lead, location, initial month) = 

\[ a \cdot A + b \cdot B + c \cdot C + \ldots \]

Honest hindcast required 1950-present. Covariance \((A,B), (A,C), (B,C), (A, \text{obs}), (B, \text{obs}), (C, \text{obs})\) allows solution for \(a, b, c\) (element, lead, location, initial month)
SST Consolidation Forecast
Nino 3.4

Fcast. Made: 9 JUN 2004

Anomaly

2004  Target Month  2005

Cons  CCA  NCEP  CA  MKV  CFS  OBS
Model Forecasts of ENSO from Apr 2008

NINO3.4 SST Anomaly(°C)

JFM Mar MAM AMJ MJJ JJA JAS ASO SON ONS NDJ DJF

Dynamical Model:
- NASA GMAO
- NCEP CFS
- JMA
- SCRIPPS
- LDEO
- AUS/POAMA
- ECMWF
- UKMO
- KMA SNU
- ESSIC ICM
- ECHAM/MOM
- COLA ANOM
- MetFRANCE
- JPN-FRCGC
- COLA CCSM3

Statistical Model:
- CPC MRKOV
- CDC LIM
- CPC CA
- CPC CCA
- CSU CLIPR
- UBC NNET
- FSU REGR
- UCLA-TCD
Forecast *Nino3.4* SST anomalies from CFS

Temperature in K

Latest 6 forecast members
Earliest 6 forecast members
Other forecast members
Forecast ensemble mean
0lv2 observation

PDF correction: Forecast \textit{Niño3.4 SST anomalies} from CFS

- Latest 8 forecast members
- Earliest 8 forecast members
- Other forecast members
- Forecast ensemble mean
- OIv2 observation

Last update: Tue Apr 21 2009
Initial conditions: 10 Apr 2009 - 19 Apr 2009
Assume a method in the madness:

\[
\text{OFF(icial) = CON(solidation) = } \alpha \times \text{Tool A + } \\
\beta \times \text{Tool B + } \\
\gamma \times \text{Tool C + etc}
\]

where the coefficients are determined (each month again) from a track record for each tool, 1981-present for Nino3.4, and 1955-present for US T&P.
A-posteriori verification:

The bottom line (all leads/all seasons); JFM95-FMA2002, Skill of CPC TEMPERATURE Forecasts:

<table>
<thead>
<tr>
<th></th>
<th>SS1</th>
<th>SS2</th>
<th>Coverage</th>
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<tbody>
<tr>
<td>OFF</td>
<td>22.7</td>
<td>9.4</td>
<td>41.4%</td>
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<tr>
<td>CCA</td>
<td>25.1</td>
<td>6.4</td>
<td>25.5</td>
</tr>
<tr>
<td>OCN</td>
<td>22.2</td>
<td>8.3</td>
<td>37.4</td>
</tr>
<tr>
<td>CMF (now old)</td>
<td>7.6</td>
<td>2.5</td>
<td>32.7 (1st 4 leads only)</td>
</tr>
</tbody>
</table>

SS2=SS1*coverage (for 3 equal class system)
Skill in SST Anomaly Prediction
Nino-3.4 (DJF 97/98 to DJF 03/04)

Anomaly Correlation (%)

Forecast Lead (in Months)

- CFS
- CMP14
- CCA
- CA
- CONS
- MARKOV
Skill in SST Anomaly Prediction
Nino-3.4 (DJF 81/82 to DJF 03/04)

Anomaly Correlation (%)

Forecast Lead (in Months)

CFS
CMP14
CCA
CA
MARKOV
Issues of ‘format’ and protocol

- Article of faith: uncertainty shall be conveyed by a probability format.
- Except for a few specialized users we cannot provide a full probability density function.
- Protocol to make a pdf palatable (on a map).
- Three classes (B, N, A); equal classes.
  - Absolute probability, probability anomaly.
- CL-option (I, CP, CL, EC).
Source: Dave Unger. This figure shows the probability shift (contours), relative to $100*1/3^\text{rd}$, in the above normal class as a function of a-priori correlation ($R$, y-axis) and the standardized forecast of the predictand ($F$, x-axis). The prob.shifts increase with both $F$ and $R$. The $R$ is based on a sample of 30, using a Gaussian model to handle its uncertainty.
Fig. 9.3: The climatological pdf (blue) and a conditional pdf (red). The integral under both curves is the same, but due to a predictable signal the red curve is both shifted and narrowed. In the example the predictor-predictand correlation is 0.5 and the predictor value is +1. This gives a shift in the mean of +0.5, and the standard deviation of the conditional distribution is reduced to 0.866. Units are in standard deviations (x-axis).
Glorious moments

ENSO composite
glorious moments
(not unique for T)

ENSO composite
Trends revisited
**B N A at 102 US locations**  
(assumed to be 1/3rd, 1/3rd, 1/3rd, based on 30 year normals period)

<table>
<thead>
<tr>
<th>Year</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Year</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
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<td>26</td>
<td>28</td>
<td>46</td>
<td>1996</td>
<td>36</td>
<td>34</td>
<td>30</td>
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<tr>
<td>1997</td>
<td>27</td>
<td>32</td>
<td>41</td>
<td>1998</td>
<td>08</td>
<td>17</td>
<td>75</td>
</tr>
<tr>
<td>2000</td>
<td>13</td>
<td>24</td>
<td>63</td>
<td>2001</td>
<td>22</td>
<td>20</td>
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<td>15</td>
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<td>53</td>
<td>2002</td>
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<td>15</td>
<td>38</td>
<td>47</td>
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<td>20</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>07</td>
<td>34</td>
<td>59</td>
<td>2006</td>
<td>11</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>10</td>
<td>34</td>
<td>56</td>
<td></td>
<td></td>
<td></td>
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</table>

19 30 50% 1995-2007

**B N A at 102 US locations**

-14 -3 +17  (‘Probability anomalies’ ; SS2=~26)
Distribution of B, N and A in the last 14 years:

<table>
<thead>
<tr>
<th>Year</th>
<th>B</th>
<th>N</th>
<th>A</th>
<th>Notes</th>
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<tr>
<td>1995</td>
<td>26</td>
<td>28</td>
<td>46%</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>36</td>
<td>34</td>
<td>30</td>
<td>These three years were not very biased</td>
</tr>
<tr>
<td>1997</td>
<td>27</td>
<td>32</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>08</td>
<td>17</td>
<td>75</td>
<td>suddenly strongly A, Kicked off by ENSO???</td>
</tr>
<tr>
<td>1999</td>
<td>13</td>
<td>24</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>22</td>
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<td>58</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>15</td>
<td>32</td>
<td>53</td>
<td>(Normals changed!, but not much relief)</td>
</tr>
<tr>
<td>2002</td>
<td>19</td>
<td>36</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>15</td>
<td>38</td>
<td>47</td>
<td>Bias only mild for these three years. Official gipper came down because trend wasn't that strong!!!</td>
</tr>
<tr>
<td>2004</td>
<td>20</td>
<td>33</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>07</td>
<td>34</td>
<td>59</td>
<td>accelerating warming?????</td>
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<tr>
<td>2006</td>
<td>10</td>
<td>28</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>10</td>
<td>34</td>
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<tr>
<td>2008</td>
<td>31</td>
<td>41</td>
<td>27</td>
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</table>
One year ago.

Now 

Hua van den Boel, CPC/NCEP/NWS/NOAA: uninterpolated OCN; data thru January 2005

Hua van den Boel, CPC/NCEP/NWS/NOAA: uninterpolated OCN; data thru January 2007
JAS: The 'king' of the seasons for P-OCN
SS2 of retro-OCN JFM
OVERALL: Temp SS2=15.4
Seasonality SS2 OCN seasonal forecast 1995 - 2 - Mar 2007 T(12.5) & P(3.0)

SS2 value vs central month of season

-5 0 5 10 15 20 25 30

0 1 2 3 4 5 6 7 8 9 10 11 12 13

Temp Precip
Heidke Score (SS): 
\[(H-E)/(T-E)\] 
\[2 \times SS \approx \text{correlation}\]
SS2 of OCN 1962-2006 year b
overall: Temp SS2=12.5 Precip SS2=5.1

OCN introduced
Table 1. Weights (X100) of the constructed analogue on global SST with data thru Feb 2001. An example.

<table>
<thead>
<tr>
<th>Yr(j)</th>
<th>Wt($\alpha_j$)</th>
<th>Yr</th>
<th>Wt</th>
<th>Yr</th>
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<td>57</td>
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<td>69</td>
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<td>80</td>
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<td>91</td>
<td>7</td>
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<td>81</td>
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<td>11</td>
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<td>-3</td>
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<td>-2</td>
<td>82</td>
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<td>85</td>
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<td>1</td>
<td>88</td>
<td>0</td>
<td>99</td>
<td>26</td>
</tr>
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</table>

sum    -24   sum    -7    sum    +4    sum    +86

CA-SST(s) = 3 $\alpha_j$ SST(s,j), where $\alpha_j$ is given as in the Table.
Table 1. Weights (X100) of the constructed analogue on global SST with data thru Feb 2001. An example.

<table>
<thead>
<tr>
<th>Yr(j)</th>
<th>Wt (α_j)</th>
<th>Yr</th>
<th>Wt</th>
<th>Yr</th>
<th>Wt</th>
<th>Yr</th>
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<td>-2</td>
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<td>1</td>
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<tr>
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<td>73</td>
<td>1</td>
<td>84</td>
<td>-1</td>
<td>95</td>
<td>7</td>
</tr>
<tr>
<td>63</td>
<td>-1</td>
<td>74</td>
<td>1</td>
<td>85</td>
<td>3</td>
<td>96</td>
<td>2</td>
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<tr>
<td>64</td>
<td>-3</td>
<td>75</td>
<td>2</td>
<td>86</td>
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<td>97</td>
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<tr>
<td>65</td>
<td>-8</td>
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<td>5</td>
<td>87</td>
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</tr>
<tr>
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<td>1</td>
<td>88</td>
<td>0</td>
<td>99</td>
<td>26</td>
</tr>
</tbody>
</table>

sum   -24   sum   -7    sum   +4    sum   +86

CA-SST(s) = 3 ∑_j α_j SST(s,j), where α_j is given as in the Table.

OCN-SST(s) = 3 ∑_j α_j SST(s,j), where α_j=0 (+1/K) for older(recent) j.
Trends in lower boundary conditions?: global SST
EOFs for NDJ global SST 1948-2006
Trends in lower boundary conditions?: global Soil Moisture
Soil Moisture EOF  September 1948–2003

EOF1 (seed=1972)

EOF2 (seed=1961) (partial 1)

EOF1 EV=8.9%

EOF2 EV=6.4%
normal EOT JFM 1948–2004 HGT 500 mb
EOT1 (21.1%EV) (bspnt=65N,50W)  EOT2 (16.2 %EV) (bspnt=45N,160W)(partial 1)
The rest is extra
Metric

48 MRM Sfc. T. Heidke Skill

[Graph showing the 48 MRM Sfc. T. Heidke Skill over the time period from December 1998 to December 2003. The graph shows periodic fluctuations with peaks and troughs.]

Legend: Skill
Correlation (upper panel) between OCN forecast and observed values of seasonal temperature and the optimal K (lower panel). Local significance levels are shown for 99%, 95% and 90%. K is zero if the skill is not significant.
Model Forecasts of ENSO from Feb 2004

Dynamical Models:
- NASA
- NCEP/EM
- JMA
- SCRIPP
- LDEO
- AUS/CSIF
- AUS/FOA
- ECMWF
- KOREA S
- ZHANG K
- ECHAM
- COLA AN

Statistical Models:
- CPC MRK
- CDC LIM
- CPC CA
- CPC CCA
- CSU CUF
- UBC NLC
- FSU REG
- UCLA TC

SST Consolidation Forecast
Nino 3.4
Fcast. made: 8 May