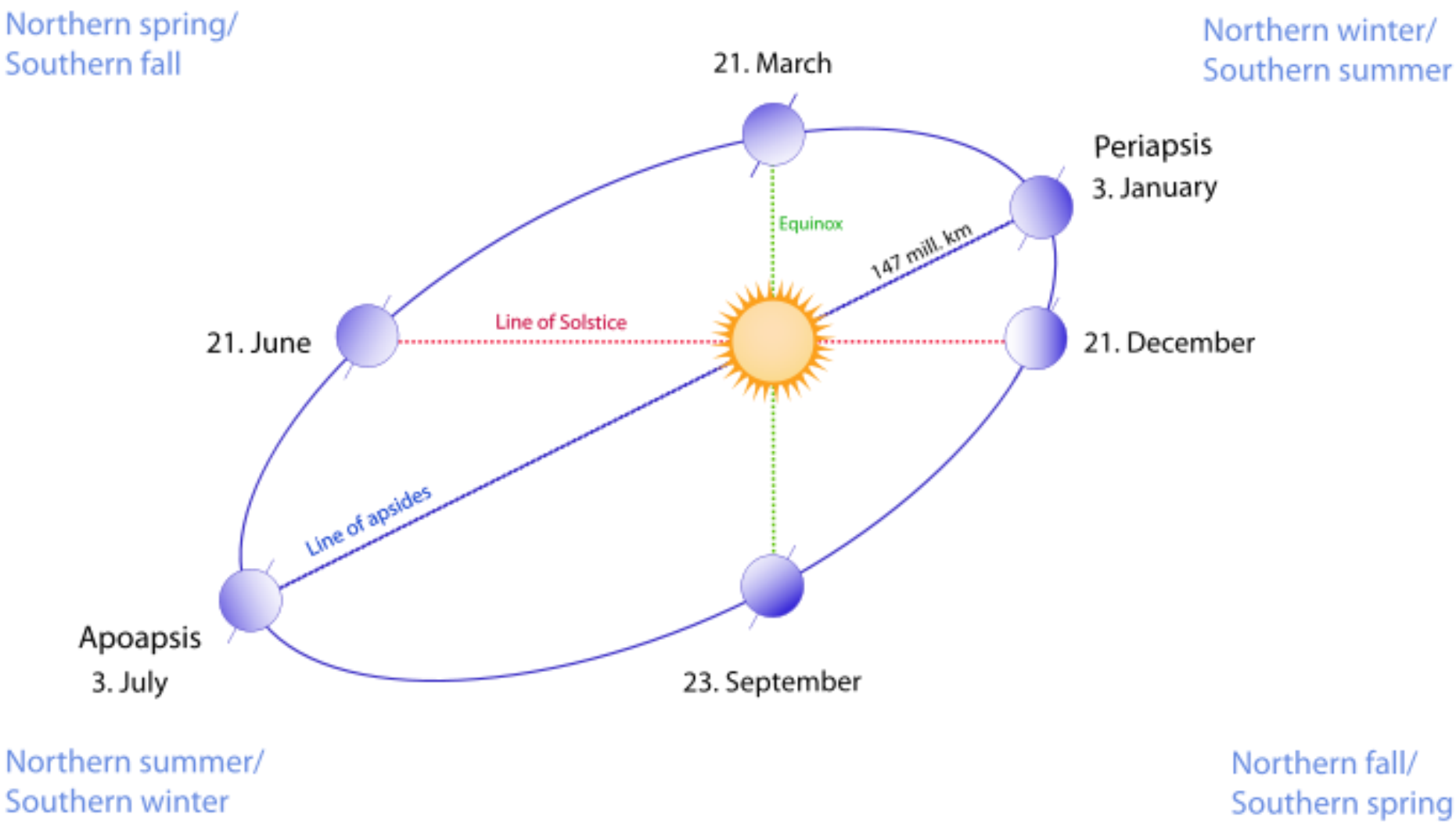
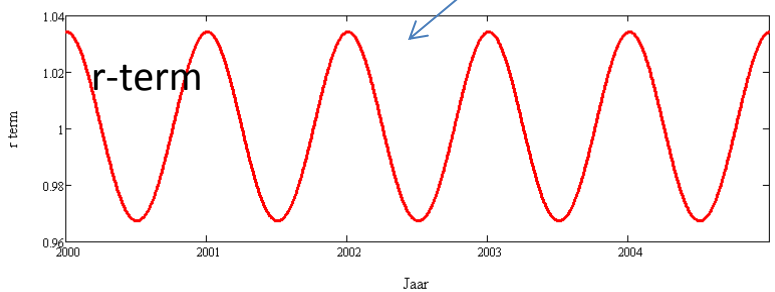
A more nuanced view of the climatological annual cycle

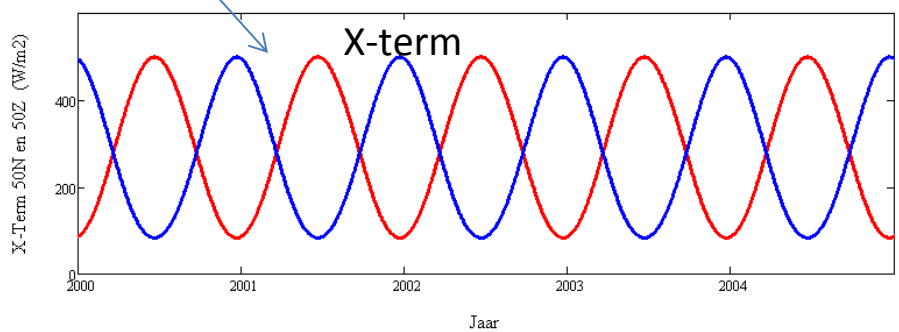
Huug van den Dool



Tropical year 365.25- days (365.2419)
Anomalistic year, 365.25+ days (365.25964)
Gregorian Calendar
Eccentricity, obliquity, perihelion moves around in 20,000+ years

$$\overline{Q_{TOA}} = \left(\frac{r_0}{\overline{r}}\right)^2 \frac{I_0}{\pi}\left[\frac{N_d}{2}\sin\delta\sin\phi + \cos\delta\cos\phi\sin\left(\frac{N_d}{2}\right)\right]$$





Calculated as per Meeus(1979) recipes for day-length, r, and declination.

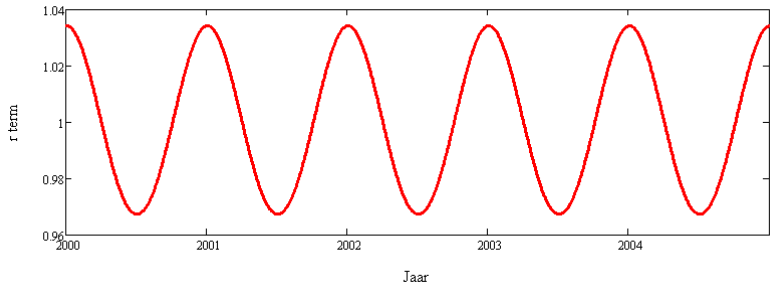
The above is for incoming radiation. (Forcing)

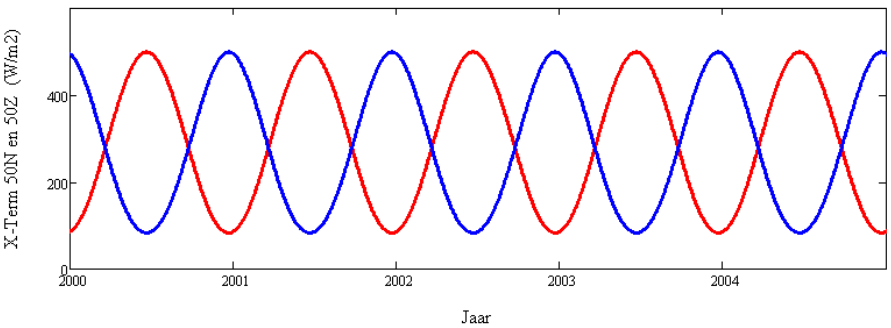
Ambition:

To retrieve the two ingredients of the annual cycle from near surface observations (T2m), the response!.

$$\overline{Q_{TOA}} = \left(\frac{r_0}{\overline{r}}\right)^2 \frac{I_0}{\pi}\left[\frac{N_d}{2}\sin\delta\sin\phi + \cos\delta\cos\phi\sin\left(\frac{N_d}{2}\right)\right]$$

short hand: $Q = (r_0/r)^{**}2 \;\; X$





r-term = $(r_0/r)^{**}2$ is expressed as annual mean (=1) plus a time varying part.
i.e.
$1+h(t) = 1+c*\sin(\omega_r t)+d*\cos(\omega_r t)$
dimensionless

X-term is expressed as annual mean X_0 plus a time varying part.
i.e.
$X_0 + g(t) = X_0 + a*\sin(\omega_X t)+b*\cos(\omega_X t)$
in W/(m*m)

Note $Q = (1+h)(X_0 + g) = X_0 + g + X_0\, h + gh$

While $Q = (1+h)(X_0 + g) = X_0 + g + X_0 h + gh$

We note that X_0 does not necessarily equal Q_0,
(it only would if we had 21,000 years of data),
so we write $X_0 = Q_0 + e$, where e is presumably small constant

Therefore $Q = (1+h)(Q_0 + e + g) = Q_0 + g + (Q_0 + e)\, h + gh + e$

Given multi-year daily data f(t) say at an extreme land climate station

We use daily data 1981-2010 at a gridpoint in North Dakota.
10,957 days, including the 7 leap days.

Using daily data is absolutely essential

The monthly mean 30 yr climatology (Celsius) is as follows:

Jan	feb	mrt	apr	may	jun	jul	aug	sep	oct	nov	dec
-7.9	-5.0	1.8	11.3	17.9	23.2	27.9	27.8	20.8	11.6	1.9	-5.9

Given multi-year daily data f(t) say at an extreme land climate station

And an approximate equation to reconstruct data:

$f^r(t) = (1+c*\sin(\omega_r t)+d*\cos(\omega_r t)) * (f_0 + e + a*\sin(\omega_X t)+b*\cos(\omega_X t))$

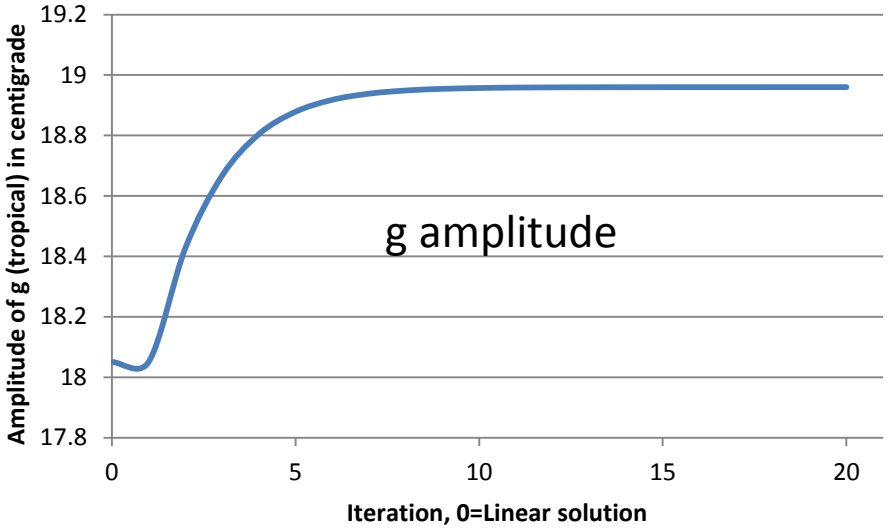
Can we extract a, b, c, d and e ? from f(t), 1981-2010,

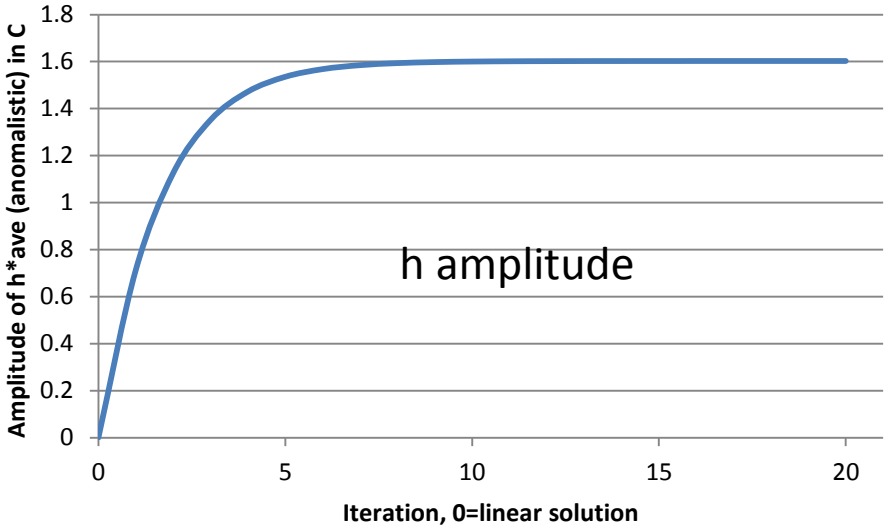
We try iterative minimization of the summed squared difference between f and f^r over all time levels.
f_0 is removed from input data f.

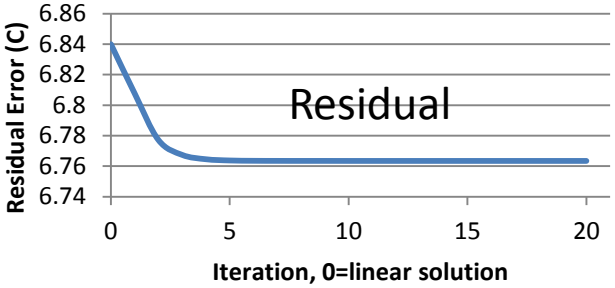
Note: $f^r(t) = g(t) + h(t) * (f_0 +e) + g*h + e$
Mainly additive and linear,
but g*h and h*e are non-linear terms.
Also the sine waves do NOT fit an integer number of times in the time series. (Not strictly harmonics)

Iterative approach

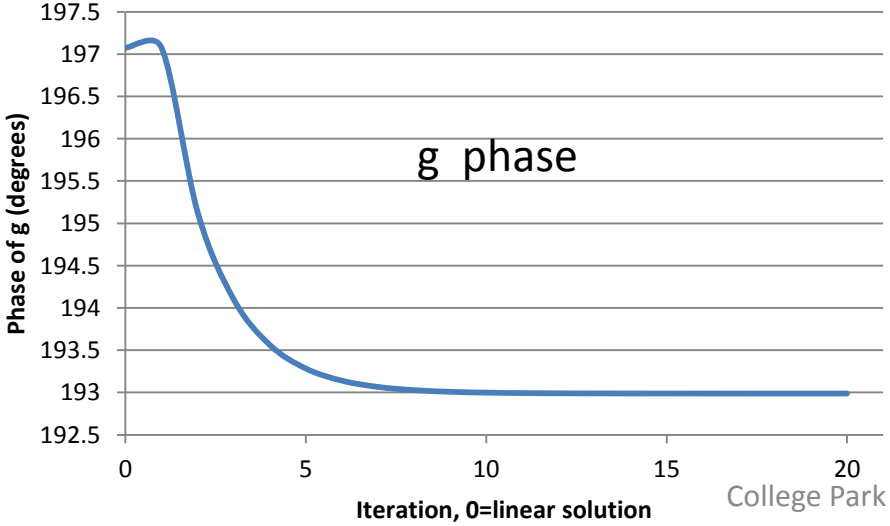
- Assume we know h, denoted h^0 , the zeroth guess. Then minimization of $(f^r - f)$**2 is linear in g. This yields zeroth guess a, b and e, thus g^0 .
- Assume we know g^0. Then minimization of $(f^r - f)$**2 is linear in h. The yields c and d, thus h^1 .
- Continue until convergence if possible.
- Questions. Is there a solution, how sensitive? is the solution unique etc. (as per this method). Start with g or h?
- Linear solution h=0 and e=0. The first guess for g.

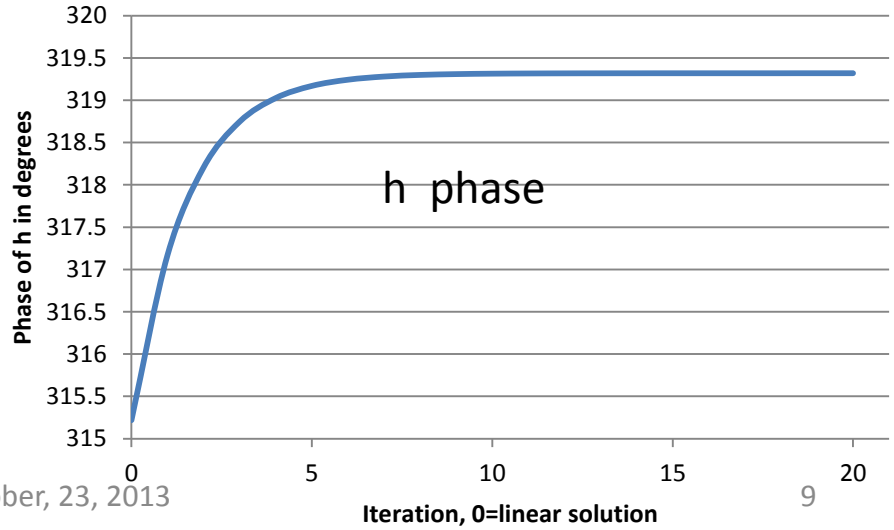

g amplitude
Amplitude of g (tropical) in centigrade
19.2
19
18.8
18.6
18.4
18.2
18
17.8
0
5
10
15
20
Iteration, 0=Linear solution


h amplitude
Amplitude of h*ave (anomalistic) in C
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
Iteration, 0=linear solution

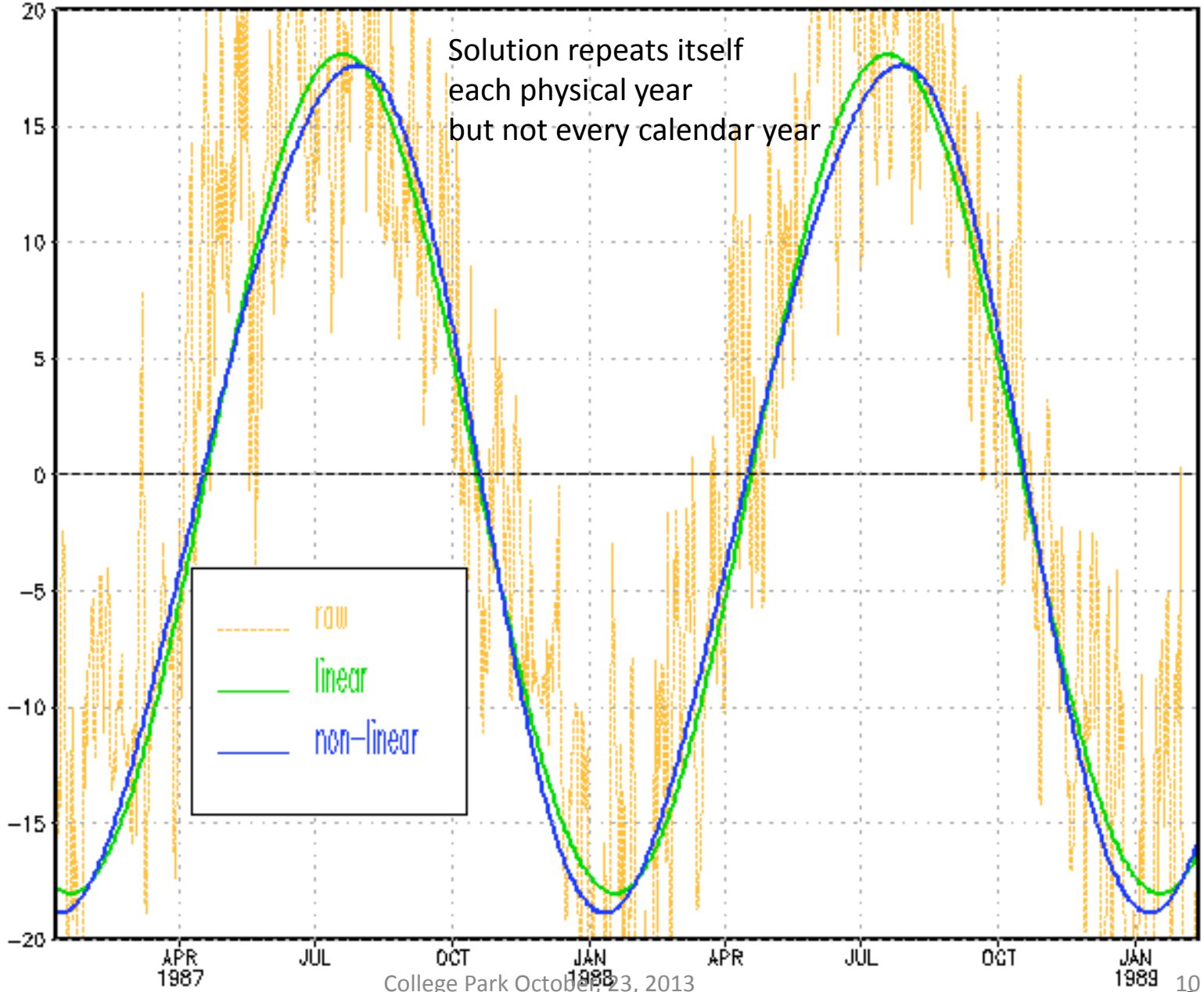

Residual
Residual Error (C)
6.86
6.84
6.82
6.8
6.78
6.76
6.74
0
5
10
15
20
Iteration, 0=linear solution

EV>100%


g phase
Phase of g (degrees)
197.5
197
196.5
196
195.5
195
194.5
194
193.5
193
192.5
0
5
10
15
20
Iteration, 0=linear solution

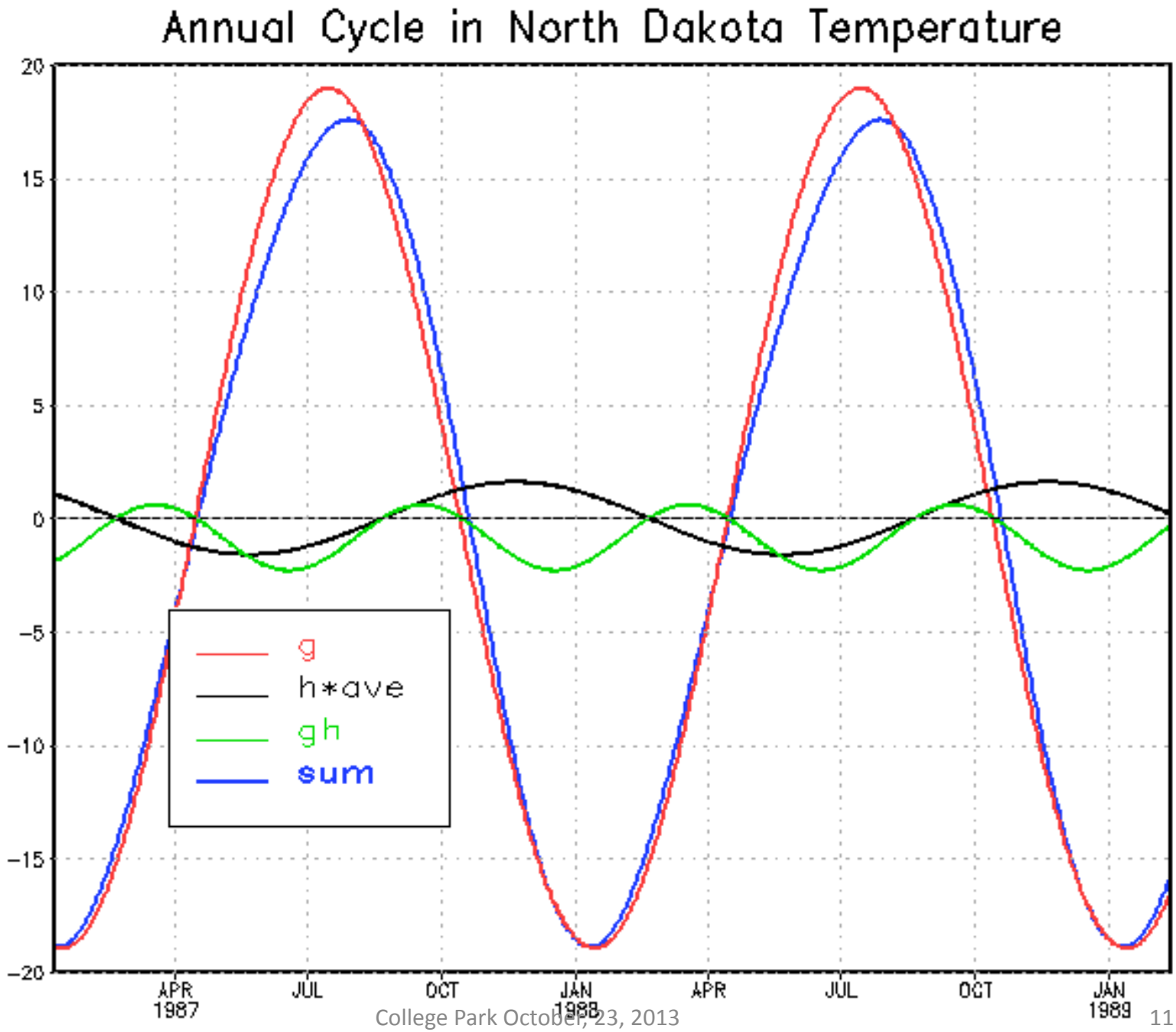

h phase
Phase of h in degrees
320
319.5
319
318.5
318
317.5
317
316.5
316
315.5
315
0
5
10
15
20
Iteration, 0=linear solution

Annual Cycle in North Dakota Temperature

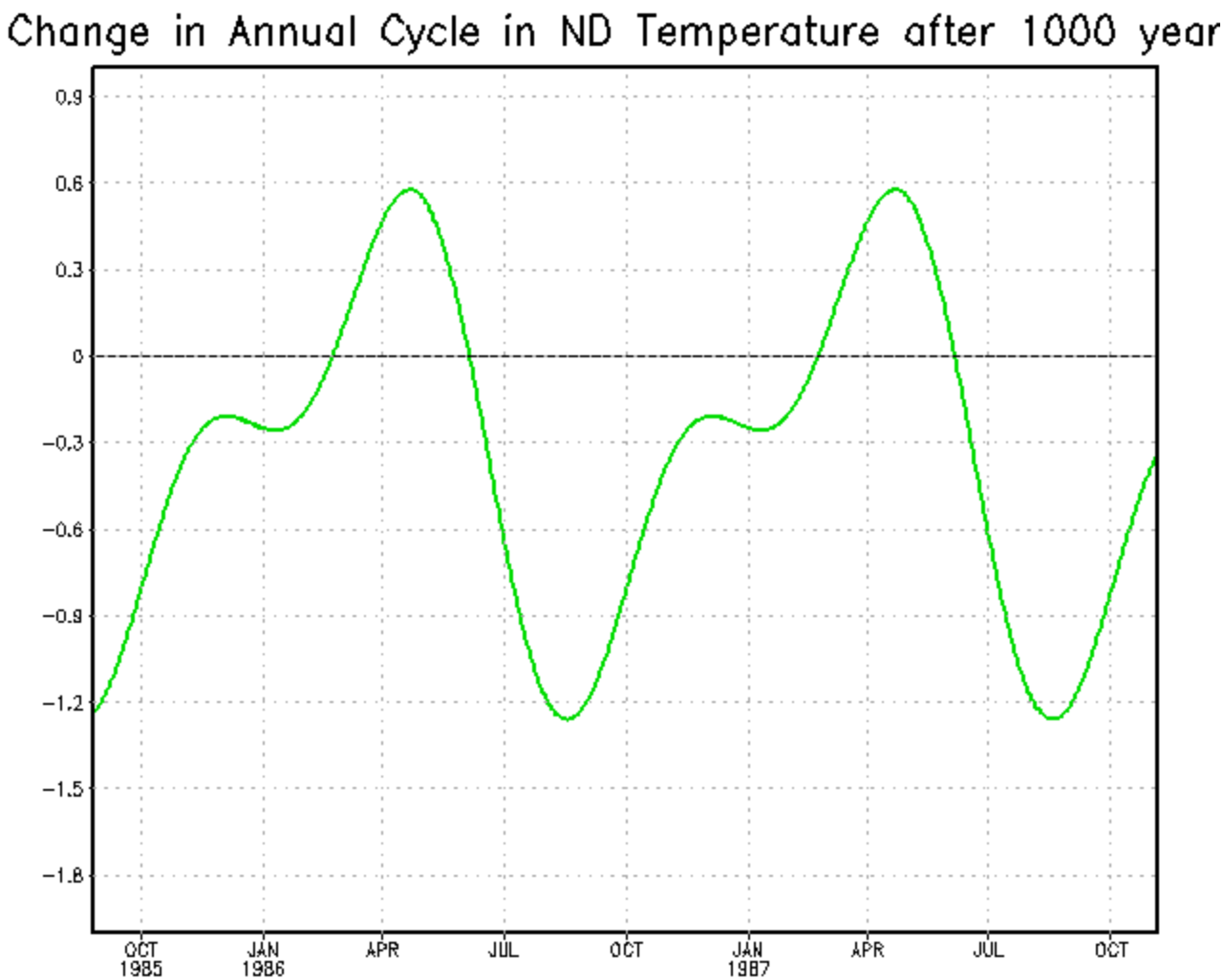


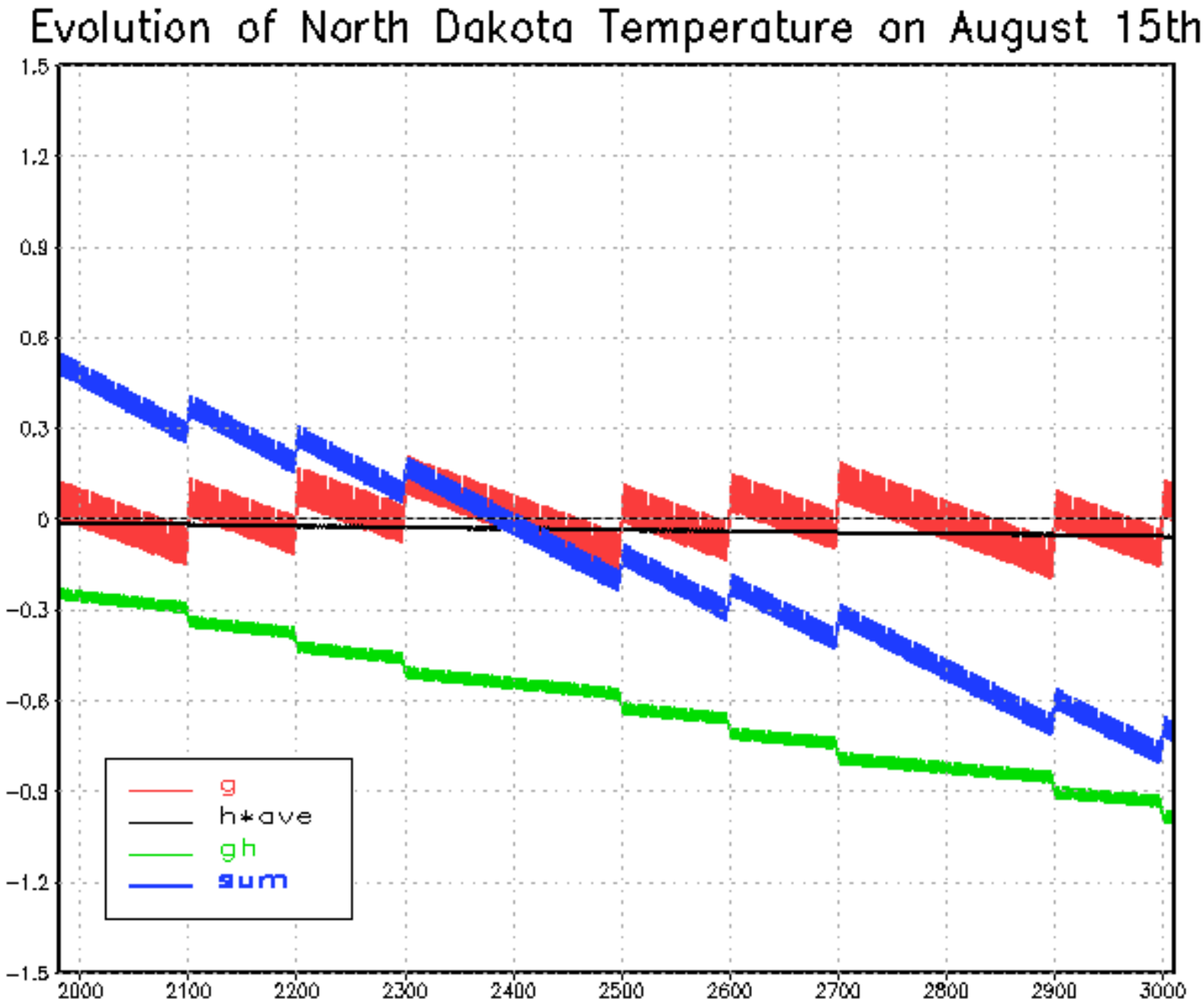
← 1981

2010→


Annual Cycle in North Dakota Temperature
20
15
10
5
0
−5
−10
−15
−20
APR 1987
JUL
OCT
JAN 1988
APR
JUL
OCT
JAN 1989
g
h*ave
gh
sum

We can extrapolate the solution to other climates, namely different perihelium, different eccentricity, and different obliquity. Example 1000 years later.




Evolution of North Dakota Temperature on August 15th
1.5
1.2
0.9
0.6
0.3
0
−0.3
−0.6
−0.9
−1.2
−1.5
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
g
h*ave
gh
sum

Conclusions

- We have (more or less) succeeded in writing the climatological annual cycle in surface air temperature in the same way as the sum and product of two annual cycles in solar radiation at the top of the atmosphere.
- Does not work everywhere. Not yet?

PS

You want to join?????

Basic Metrics and Protocol for CPC Forecast Tool Evaluations

June 2013 (Huang, Unger, van den Dool)

The metrics and protocol are intended to be
basic but broad enough to capture different aspects of evaluations,
for different types of forecasts and for different major climate henomena.

The focus is to evaluate the skills of new and experimental forecast tools
(both statistical and dynamic) for their impacts on CPC operations.

1. Basic Metrics

The metrics include different aspects of verifications including error/accuracy, skill scores, conditional statistics, reliability, biases, and etc. and three types of forecasts (namely, deterministic, categorical, and probabilistic). The metrics are consistent with those used in the CPC real-time verification system and at many places elsewhere.

<u>Deterministic/Continuous</u>:

- Anomaly Correlation (AC)
- Root Mean Square Error (RMSE)
- Mean Absolute Errors
- Amplitude
- Biases

<u>Categorical</u>:

- Contingency Table

<u>Probabilistic</u>:

- Brier Score (BS)
- Rank Probability Score (RPS)

Hindcast Protocol

The hindcast requirements mainly follow the current NMME protocol with some modification for sub-seasonal forecast. For testing potential use of new forecast tools for operational use, developers are required to provide hindcast data to CPC/CTB for systematic evaluations.

Hindcast start times must include all 12 calendar months

Hindcast period:

- Monthly and seasonal forecasts: minimum 30 years (1982-2012)
- Sub-seasonal forecasts: minimum 10 years (during 1999-2012)

Hindcast Protocol cntd

Forecast lead time:

Monthly and seasonal forecasts: 1- 7 months

Sub-seasonal forecasts: 1- 45 days

Number of ensemble members: free

Basic data:

Monthly and seasonal forecasts: Monthly mean of T2m, Prate and SST (or more)

Sub-seasonal forecasts: Daily data of OLR, U and V at 250 and 850 hPa, Z500, Z700, T2m, MSLP, Prate

Data distributed must include each ensemble member and total uncorrected fields.

Data format: Grid 1x 1