Introduction

This text is essentially a series of notes about the NMC analyses, and when procedures changed. Two of the sections are brief reviews of published papers.

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3. NMC methods 1982-83, but also includes Sept 78-on
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1. Summary of major changes in NMC analyses.

NCAR has some daily NMC surface analyses (SLP) from 1899 that are based on hand analyzed charts. Daily 500 mb charts start Jan 1946, 700 mb H, T Jan 1947. The 300 mb heights start Jan 1950. The stratospheric analyses through 10 mb are available for July 1957 - June 1959; the main set starts Jan 1964. See NCAR TN/IA-111 for a description of the data. NCAR updates a brief inventory each year.

The main sets of NMC objective analyses start in 1963, prepared by Cressman analysis methods. NMC also made objective analyses prior to this date. The NMC N. Hemisphere octagonal grid (down to 10° to 15° N) was later extended to the equator (65 x 65 grid). Archives of these 65 x 65 point analyses start 1 Dec 1974.

The NMC global 2.5° archives (surface - 50 mb) start 1 July 1976. NMC linearly interpolated the 65 x 65 N. Hemisphere grids from these 2.5° grids to continue the archives. NCAR continued to extract the subset of points for 47 x 51 octagonal grid (1977 point) from the 65 x 65. These archives are located at NCAR and NCDC, not fully at NMC.

The best NMC stratospheric analyses (70 - 10 mb) have been prepared by special NMC programs. These became global in Oct 1978 and were extended to 0.4 mb. The grids are 65 x 65 grids for each hemisphere.
To make 70 mb analyses, thicknesses are stacked up from the operational global 100 mb analyses. However, a separate NMC Hough global analysis was actually made through 26 July 1984. The stratospheric analyses were stacked on the 100 mb from this instead of on the operational GDAS until this date. The upper air analysis section felt that this gave better stratospheric results. The main NCAR (and NCDC) archives include only the 100 mb from the GDAS. NCAR has separately obtained archive tapes that include the 100 mb from Hough, on which the stratosphere was stacked.

A separate NMC tropical analysis produced fields for 48S - 48N from 1968 through 1 Dec 1974. Then these grids (about 5 degree resolution) were interpolated from the global analyses.

The global 2.5 degree lat-lon analyses from 1 July 1976 have H, T, U, V for 1000 - 50 mb (levels 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50). Humidity in boundary layer and at levels 1000 - 300 mb. SLP starts 8 Dec 1977, SFC Press starts 21 Sept 1978, SST starts 16 May 1979, Boundary layer (U, V, RH, theta) starts 6 June 1980. Surface T is available (but derived from heights). There are also fields of three layers of RH in the atmosphere, and one of precipitable water.

Other datasets have global stratospheric analyses for H, T at 70, 50, 30, 10, 5, 2, 1, 0.4 mb.

General assessment of analyses: As years go by, the improvement in forecast models should also be improving the analyses over the poor data areas. Also the availability of satellite VTPR sounder data in late 1972 and TIROS-N TOVS in 1979 should have improved these poor data regions. However, I believe that analyses of heights at constant pressure levels from 1963 (and in many respects from the late 1940s) should be relatively consistent up to the present time for 20 N - Pole. For at least sfc - 100 mb. (Roy Jenne, 1986)

A summary of the primary periods with differing analysis methods follows:

1963 (and before) - Sept 74. Analysis methods stable. Only the N. Hemisphere. Used the Cressman analysis method. Simple data weighting versus distance from grid point. In many areas this method should produce results comparable to the OI methods used in later years. The procedure included a lot of "engineering." Smoothing filters were an integral part of the procedure. Over the ocean, there is extra data at the surface and 300 mb (aircraft). NMC first analyzed these levels and used them to adjust the first guess fields before all analyses were made. This kind of engineering should help.

10 Sept 1974 - 21 Sept 1978. The Hough Function analysis method was started in production. This was a major change. There should not be much difference from the old analysis methods at latitudes such as 20-90N or 20-90S. The tropical strip winds prepared by these Hough
methods are poor.

NOTE: 12 Jan 1977 - NMC went from a 12 hour update cycle to a 6 hour cycle. This includes more data, but isn't expected to either improve or degrade the quality of the analyses significantly.

22 Sept 1978. The optimal interpolation method (OI) was put into production. This was a major change. However, the analyses probably are not very different from Hough in middle and high latitudes. These analyses are for surface to 50 mb.

NOTE: The separate set of stratospheric analyses mentioned below should be used instead of 70 or 50 mb analyses from this GDAS program.

References


NOTE: NCAR has many notes and publications about NMC analyses that may be viewed on request when visiting the NCAR Data Support Section. Some additional notes can be mailed.

Cautions (Sept 1986)

- Winds in the tropics were poor during Hough (74-78).
- NMC temperature analyses (surface and UA) have been derived from thicknesses for some years. Don't expect a good match with observations, especially at the surface.
- Analyses of SLP have not used synoptic code observed SLP data over land for some years, and the procedures have changed. It is probably better to use Navy analyses for this variable. (Roy Jenne, Sept 1986)

2. NMC changes Sep 1978 - Jan 1982


The NMC OI analysis scheme started 22 Sept 1978. The "final" analyses are based on a 9.5 hour cutoff for data receipt. They also are based on a 6 hour analysis/forecast cycle (GDAS - global data assimilation system). It is described by McPherson, et al (1979).
11 Oct 1979: replace the 5 x 5° lat-lon analysis grid with a 3.75° modified Kurihara grid. Revised the data buddy check so that it not only rejects bad data as before, but will accept some data outside of reject limits if it agrees with neighbors.

A table is given that compares the new 12 layer (24 wave) spectral model with the previous 9 lvl (2.5°) grid forecast model. (These review notes by R. Jenne.)

Reference:


3. NMC analysis changes Sep 1978-Dec 1983


The basic analysis grid has points about every 2.88° lat. There are 78 points around the equator (each 4.6° long), 56 points at 44.64N, and 10 points at 82.07N. The size of an analysis cell is about 513 Km x 320 Km. The data on the basic analysis grid is not saved; the archives are on 2.5° lat-lon grids or NMC 65 x 65 polar stereo grids (318 Km at 60N). NCAR and Asheville have the data.

Sept 1978 - analyses were done on sigma coordinates

27 May 1980 - Grid point global prediction model for GDAS guess changed to 24 wave global spectral model. And normal mode initialization started.

13 Jan 1982 - Gradient winds derived from satellite temperatures were used.

14 Aug 1982 - Analyses changed to pressure coordinates. (1000, 850, 700, etc.) The derived boundary is probably of poorer quality than before.

The paper also lists the error statistics that are assumed by the analysis procedure for different types of data. It also shows comparisons of height and wind analyses with rawinsonde observations for a three-year period. The usual differences are about 15 m (RMS) heights and 6.5 m/sec (RMS) winds. (These review notes by R. Jenne.)

4. NMC Analysis Characteristics (From talk with Cliff Dey, NMC) (Roy Jenne, 15 Sept 1983)

Prior to August 1982, the NMC final analysis OI method made its analysis in sigma coordinates and used temperature and wind data from surface reports and upper air stations.

On 14 Aug 1982, their new Optimal Interpolation (OI) scheme was put
into production. This produces analyses at the surface and at the levels 1000, 850, 700 mb, etc. The method uses the guess from the forecast model (which uses sigma coordinates). It first analyzes for surface pressure. Surface winds are used only to help analyze for surface pressure. The surface pressure gives a level on which the satellite thickness data can be stacked. Then they use the 01 scheme to analyze for the upper air data at pressure levels, using only height and wind data (temperature not directly used).

The resulting pressure level analyses are interpolated to sigma surfaces. The sigma levels are 1.0, 0.925, 0.800, etc., (gives pressure levels of 1000, 925, 800 mb if the surface pressure is 1000 mb). The analyses are then run through the normal mode initialization scheme. The air temperatures at the surface and at pressure levels are derived from the thicknesses. It appears that there is no real model of the boundary layer during this process. It is likely that the procedure produces very poor analyses of surface air temperature.

5. NMC Stratospheric Analyses (by Roy Jenne, 4 Jan 1982)

Talk with Mel Gelman, NMC, about analyses. (1000 - .4 mb grids.)

They use the Hough analyses up through 100 mb. In the N. Hemisphere they use available raobs in the analyses for 70-10 mb. In the S. Hemisphere they did use them but as of 8 Oct 1980 they quit using raobs because NMC felt the analyses were more consistent without them. The use of raobs would result in troughs and bulls-eyes, even around good data. Also, they couldn't protect well against bad raobs.

May 1981: The NMC high altitude analysis section makes special analyses for 70 - .4 mb. These are better than the 70 and 50 mb analyses from the GDAS analyses. In general, these have not been affected by changes in the NMC package of sfc-50 mb analyses (GDAS).

I talked with the high altitude section at NMC (May 1981) and they didn't remember any major changes in the 1975-77 time period (70 - 10 mb analyses). However, they did say that there were some changes when the satellite temperature retrievals were used or not used over the ocean areas. They are trying to find information about when such changes were made.

6. NMC Stratospheric Analyses (Notes by Roy Jenne, 17 Sept 1984.)

In 1978-79 the high strato analyses first used VTPR data, and later TIROS-N. One channel of the SSU was bad on TIROS-N. A comparison showed that analyses for the whole period are probably quite good up through 2 mb. At first 1 mb is not too good, then OK with a SSU instrument having all three channels after TIROS-N was replaced. The .4 mb analyses aren't very good during any of the period.

This information was from John Gille, NCAR, based on an Oxford Report which should be printed in Volume 11 of the MAP Handbook.
7. NMC Analyses

Talked with Bob Kistler (with Cliff Dey, NMC), about analyses (Roy Jenne, 23 March 1985)

Prior to 22 March 1984, NMC did a surface pressure analysis using land station pressure, ship, buoy, etc. This was used to stack satellite retrievals on. To get data under the model terrain, they extrapolated down, using model temperatures.

Changes put in 22 March 1984: They now first analyze for a 1000 mb level height. Use ships and buoys over ocean. Don't use any data from synop stations over land. Use 1000 mb heights from raob stations. High elevation stations do extrapolate their data down to calculate heights below the surface. NMC thinks their present 1000 mb heights and SLP maps look more (than before) like the usual charts for these levels. They think this is, therefore, an improvement. With this change, the surface pressure field is calculated from the pressure-level analyses, and the model terrain. It is therefore more in balance with the UA analyses and the changes during initialization were reduced to about half the previous values.

One reason for the change had to do with the computer change to the CDC-205. They did not have the people to convert the long, cumbersome code for the surface pressure analysis so that it would run on the 205.

6 Sept 1984 (12Z) The tropical wind analyses (10N - 10S) were changed from bivariate to univariate. This permits the analysis of divergent wind corrections. (From the NMC paper "1984 Summary of NMC Operational Global Analyses" by Dey, et al.)

Temperature analyses are derived from heights

In analyses before and after this 22 Mar 84 change, all temperatures (except SST) are derived from the heights. The program doesn't look for surface inversions from raobs (maybe in the future). Thus, analyses of surface air temperature and 1000 mb temperature are poor.

8. Quality of NMC and Australian Analyses Over S. America
(Memo by Roy Jenne, 12 Jan 1982)

Pedro Silva Dias from INPE in Brazil is visiting NCAR. He compared NMC and Australian analyses with observed data over S. America. He said that the NMC analyses were much better than those from Australia. In fact, he was quite pleased with the NMC tropical strip analyses. I think that Australia has had trouble in obtaining the observed data from S. America.

He did, however, note that it was a problem that the Hough method at NMC (1974-78) stopped the mean Hadley cell and stopped any local divergence.
9.0 NMC Analyses and Forecast Changes (Operational on 28 May 1986, 12Z).
(Roy Jenne 13 May 1986; revised 24 Sept 1986.)

9.1 Analyses

The new NMC analysis/forecast system became operational on 30 May 1986. The resolution of the basic analysis grid was changed to have approximately twice as many points as before (resolution about 500 Km (E-W) by 250 Km (N-S)). Near the equator, a grid cell became about 2.25° Lat x 4.5° Lon. There are fewer longitude points as one approaches a pole. This is about the same longitude resolution as before and a change from 2.88° Lat. Proportionally, more points were added toward the pole. This set of analysis points allows NMC to go directly to 40 wave uninitialized analyses without loss of information.

Comments by C. Dey, 23 June 1986: (1) In the new system, the large scale divergence seems to match the activity centers in the tropics and mid latitude storms. (2) NMC sees rather large changes during initialization, especially in the tropics. Dey thinks NCAR would be better off using the uninitialized grids at pressure levels. (We agree but haven't been able to readily obtain them yet.)

The new and old analysis systems each have twelve mandatory pressure levels, and use multivariate O/I methods. The new system permits up to 33 observations to affect a grid point. These are chosen by finding which reports are most highly correlated using all nine correlation functions. The old scheme permitted 20, chosen by being closest. The new one uses satellite data over land above 100 mb.

It also calculates the true solution to the O/I matrix. It happens that the old one often hadn't converged to the correct solution.

The analyses (new and old) are done on the 12 pressure levels (to 50 mb) on grid points. These updated analyses become 40-wave spherical harmonic data which is archived. The increments are then interpolated to sigma levels (archived). These fields go through a normal mode initialization process. The heating rates for diabatic initialization come from a 2-hour model forecast run.

9.2 Use of Surface Observations

In the new analysis scheme (as in the old) surface observations are used over the ocean but not over land. Before a change in 1982, they did use surface observations over land to analyze for surface pressure. In 1982, they went to a multivariate analysis scheme in which they no longer analyzed for surface pressure. So they just used mandatory level raob data over land and calculated a surface pressure from that analysis. Also, when they moved the code to the new computer, in 1982, they didn't have room for the surface data over land. Now they do. They think that the land surface data is valuable and hope to make changes so that it can be used again. (As of May, 1986.)
9.3 Forecast

The new analysis/forecast system became operational on 28 May 1986, 12Z. The new GDAS forecast model has the features:

- 18 layer, 40 wave model vs. 12 layer, 30 waves before. The location of the new sigma levels are shown in Table 1.
- The mountains are more enhanced; uses silhouette mountains. The operational mountains were not enhanced and even had a smoother that made their ridge elevations still lower.
- The "GFDL physics" package was put in some time ago. This model has further improvements in physics (changes in convection, etc.). The new package removes some model biases.
- The new sigma layers are shown on the attached sheet.

The analyzed quantities are: H, U, V, RH. Temp, Trop Height, etc., are derived. In a post processor, the quantities derived are: Vertical velocity, surface temperature (2 m), etc.

- The forecast model doesn't have a diurnal temperature cycle yet.
- There is a diurnal cycle in the verification of 500 mb heights over the U.S. which is not understood.

9.4 The analysis archives are (all spectral):

1. Pressure level analyses (uninitialized) (most basic)
2. Pressure level analyses (initialized)*
3. Pressure levels (6 hour, 1st guess)

On Model Sigma Levels:
- 4. Analyses, uninit
- 5. Analyses, init
- 6. 6-hour forecast

The archives were 30 wave; they are 40 wave from 28 May 1986.

*NCAR gets these analyses in grid point form (2.5° lat-lon grid). Also, NMC interpolates (linear from 2.5° grids) hemispheric grids (65 x 65) which NCAR gets. The other analyses in spectral form are on many tapes at NMC and not readily available. See below.
NOTE: NMC has noted that their jet level winds are somewhat stronger than ECMWF. This is probably a good thing.

9.5 System Changes in 1985

There was only one minor change. In February 1985, NMC corrected a problem with the analysis influence function of RH data poleward of 70° lat. Minor effect, if any.

9.6 Present Spectral Archive (as of May 1986)

NMC has kept a 2-year rotating archive of analysis and selected forecast data, at R30 spectral waves from the old model. This has not had model coordinate data in it. (The new one will.) It has initialized and uninitialized data, all at pressure levels. From the medium range global model, some global spectral data are saved as well as some 65 x 65 grid data for the N Hem. They now charge $100/month for a tape of this and no one has asked for it. (Info from John Stackpole, X. 8115.)

9.7 Characteristics of the New Forecast System

Figure 2 shows that the upper level Hadley cell outflow is under better control in the new system. Figure 3 seems to show that the new system weakens the low level meridional wind too much in both the Hadley and mid-latitude cells. (Figures are at NCAR)

9.8 The above information has been mostly from Cliff Dey and Brad Ballish at NMC.

9.9 Ocean Wave Model at NMC (May 1986)

They take the 1000 mb winds and use stability to reduce them to either 19.5 m winds (for their model) or 10 m winds. They end up with winds each 6 hours from the analyses and forecast schemes. The forecast NMC ocean waves have been found to be better than Navy waves. This is because the Navy forecast model skill falls off rapidly in the first 1 or 2 days whereas the NMC forecasts have skill to about 3 days.

They have verified their winds and waves with NDBC buoys and they look quite good. NORDA did a recent study where they compared Navy and NMC waves with Geosat waves for one day. The NMC waves looked better.

I asked whether they have considered getting the surface winds from the lower model sigma layers instead of from the 1000 mb data. They have not tried that as yet.

From talk with Hong Chin, at NMC, X. 8133. (May 1986, Roy Jenne)

10. Previous NMC Forecast Models (Roy Jenne, 19 Jan 1983)
Talk with Joe Sellers, NMC

- June 1980 - the spectral model replaced the previous model for making the first guess forecast (for the next analyses) based on final time analyses.

- August 1980 - started the model for production forecasts also.

- At first it was global for part of the forecast period, then hemispheric. Now it is global to 192 hours.

- It changes resolution: 12 lvl, 30 wave to 48 hr; then 12 lvl, 24 wave to 84 hr.

- Results:
  - 500 mb and up - an improvement
  - Precip is worse. Why? Maybe the resolution but it is about the same. Maybe because of the way convection is handled?
  - Medium range forecast people quite happy with it.
  - See John Stackpole for verification information.
  - Thinks surface not much change, but better at longer hours.
  - NMC just made an in-house report giving model verification for the 3-5 day period for about the last 10 years.

- Dates of changes in their operations are usually in the NMC annual report.

- Changes in NMC analyses, late 1986. (Talk with Cliff Dey, NMC, on 9 Dec 86, by R. Jenne.)
  - 10 Sep 86. The US temperature fields (funny thickness sigma layer 6-17 and 17-18. The 17th sigma layer (about 70 mb) was too cold by about 20° in the tropics. Fixed 10 Sep. Some effect at 100 mbs. Levels of H, T much better above 100 mb now.
  - Also a change to slowly diffuse the temperature at sigma levels 17, 18 toward climatology over 25 days. This doesn't do much since satellite data keeps going into the analyses.

- 00Z 18 Nov 86. Changed the post processor to clean up the code. Just found that temperatures under ground are much worse (1000 or 850 mb), but the thicknesses are still OK.

11. Use of TIROS-N satellite soundings. (Information from Tom Schlatter, 21 Mar 1979)
On 12Z 5 March 1979, NMC began using TIROS-N soundings in its final cycle (the one which uses the multivariate statistical analysis) but only in the S. Hemisphere. Only "clear" or "partly cloudy" soundings over the oceans are being used. (no microwave)

The regression coefficients for the retrieval will be changed on Friday 23 March 1979, but soundings will be included in the analysis only in the S. Hemisphere for a while longer (about 2 weeks).

Though not all retrievals are used in the final cycle, all are archived on the Level II tapes starting on 5 March 1979.

NOTE: Other archives (incl. NCAR) have TIROS-N sounding data that can be used from 1 Jan 1979 or before.


The major change that NMC made to improve TIROS retrievals was to handle the cloudy case (microwave retrievals) better. Since rain was clobbering the info, they inspected a channel to see when rain was going on.

He said that ECMWF did reprocess the TIROS-N soundings before they made the FGGE year analyses.

12. NMC Verification Statistics, Analyses and Forecasts

John Stackpole (now in NMC automation division 301-763-8115) said that his verification statistics start in 1977 for the Northern Hemisphere and 1980 for the Southern.

The monthly statistics compare daily rawinsonde data to analysis and forecast grid data. They are prepared for the regions:

- N. Hemisphere, 30N - Pole vs 102 raob stations
  - Alaska
  - N. America, 25-60N
  - E and W, N. America
  - Europe, N. of Mediterranean
  - Pacific, EQ-30N
  - Atlantic, EQ-30N
  - Australia
  - S. America, Eq and South
  - Africa S. of Equator
  - S. Pacific Ocean

The statistics include mean error, RMS, etc., for height, temp, wind components, RH. For the levels 850, 500, 250, 100 mb. They may make a tech note sometime. John will prepare a few charts on call. His address is: W/NMC 42, Room 337, World Weather Building, Washington, DC 20233.
13. Computing at NMC

13 June 1972: NMC changed from IBM 7094 to CDC-6600. Programs were changed from assembly language to Fortran so it took awhile to get all bugs out. The 7094 had 32,768 words (36 bits each) of memory.

About 10 Sept 1974: NMC started operational analysis/forecast runs on their IBM-195. They are (23 Sept) changing codes without full checkout to be free of 6600s by 31 Oct 1974.

1987: Time needed for an analysis/forecast cycle:

Four analysis/forecast cycles in a day take 3000 sec of CPU time on a CDC-205. The wall clock time is about 1.3 times this. This is for a 40 wave, 18 layer, full physics scheme, first guess and analysis. (Does not include the long forecasts for public use.) From Cliff Dey, Dec 1986.

14. Changes in surface elevation

Summary: The model elevation changed on 14 Aug 1982 and on 28 May 1986. (Talk with Cliff Dey 20 Jan 1987.)

The mountains used in the analyses are the same as those used in the forecast model. On 14 Aug 1982 a new OI scheme was put into production. The forecast model was changed from 24 waves to 30. Therefore, the model elevation was changed. Then there were no elevation changes until May 1986. On 28 May 1986, 12Z a new system started production. The forecast model became 18 layer, 40 waves; it was 12 layer, 30 waves before. The mountains became more enhanced, used new "silhouette" mountains.

Whenever the mountains change, a field like surface (not sea level) pressure will change. For example, from 28 May 00Z to 28 May 12Z, the NMC analyzed surface pressure at 9 grid points near Boulder, CO (near the center point) is as follows:

<table>
<thead>
<tr>
<th>Analyzed Surface Pressure in mb:</th>
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<tbody>
<tr>
<td>28 May 00Z, 1986</td>
</tr>
<tr>
<td>107.5° W</td>
</tr>
<tr>
<td>42.5° N</td>
</tr>
<tr>
<td>40.0° N</td>
</tr>
<tr>
<td>37.5° N</td>
</tr>
</tbody>
</table>
The actual elevation at Boulder is about 5400 ft. (1646 m); 25 miles to the west, the elevation at the continental divide is about 11,500 to 12,500 ft. (3506 to 3811 m), with higher peaks. Standard heights at 850, 700 mb are 1457 m, 3012 m.

15. NMC tropopause analyses (Roy Jenne, 25 Aug 1977)

Talk with Phil Falkener - was with GASP before and Air Resources Lab.

NMC makes analyses of tropopause pressure and tropopause temperature. Faulkener has used NMC tropopause analyses with their GASP data. (Global Air Sampling from wide body aircraft.)

The NMC tropopause analysis archived through 00Z 17 Dec 75 was Flattery "Hough analyses". Then they put in the Gustafson method.

Both methods are bad in the tropics. They don't let tropopause go above 130 mb. Often it should be at 100 or 90 mb.

Some preference for Gustafson method anytime deep troughs develop - thus especially higher lats in colder seasons. Overall Gustafson method gives a trop that is 50 mb lower than Flattery. By 60°N only about 10 or 15 mb difference. Overall, he likes Flattery a bit better, especially for mid-lat warm seasons.

In Gustafson method they look at lapse rates but also have some decisions involving monthly climatology and various climatic zones.

16. Selected papers that discuss analyses


Shows plots of NMC, Navy, and Australian sea level pressure versus time, 1977-83. Differences between the analyses are shown.

Note by R. Jenne: We have noted that NMC does not use surface synoptic reports of sea level pressure or station pressure over land in the recent 10 years or before. Also, the methods for calculating SLP from the tropospheric analyses have changed and have not received a lot of attention by NMC. For SLP, people usually use the Navy product. (Written Sept 1986)
Table 1. NMC Spectral Forecast Model Levels

Location of the sigma levels in the new NMC forecast model (GDAS). This 40 wave, 18-layer model started in production on 28 May 1986. The older 30 wave model levels are also shown.

- **SL** = Sigma at center of layer
- **Del** = Layer thickness, sigma
- **SI** = Interfaces of layers, sigma

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>New 28 May 1986 Model</th>
<th>Old Model</th>
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<td>(SL)</td>
<td>(Del)</td>
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<td>Sigma at Layer Center</td>
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