1. METHODS

The 1/4° grid climatological mean fields of temperature and salinity for the annual, seasonal, and monthly time periods were calculated using objective analysis techniques which were basically the same as those detailed in the World Ocean Atlas 2001 temperature (Stephens *et al*, 2002, hereafter WOA01t) and World Ocean Atlas 2001 salinity (Boyer *et al*, 2002, hereafter WOA01s) for the 1° grid climatological mean fields, with differences as described below.

The objective analysis technique is a calculation of mean fields at each grid square based on weighted difference between the means at all grid squares within a given radius of influence around a gridpoint and a first-guess field at the same grid square. In the present case, for both 1° grid and 1/4° grid, the procedure was repeated three times, each time with a diminishing radius of influence. The smaller grid square size for the 1/4° grid allows us to define smaller scale features than the 1° grid. To preserve this advantage, the radii of influence for each pass through the analysis procedure was smaller as well, so as to limit the number of grid squares which would affect the climatological mean value. The size of the radii of influence for each pass through the analysis for each grid size were:

Pass	1° grid radius of influence	1/4° grid radius of influence
1	892 km	321 km
2	669 km	267 km
3	446 km	214 km

Another major difference was the amount of smoothing. The 1° climatologies were smoothed using one pass of a Shuman smoother (Shuman, 1957) followed by one pass of a gradient preserving median smoother (Rabiner *et al*, 1975) using the data from one grid square directly to the west, east, north and south, in addition to the datum from the grid square itself. The 1/4° climatologies were smoothed using only the median smoother, but using data from five gridpoints on either side of a datum in addition to the datum itself.

The first-guess field for the 1° climatological mean fields was the zonal average of all data within a subarea (Atlantic Ocean, Pacific Ocean, Mediterranean Sea, *etc.*). A first-guess field is a best guess of the probable structure of the climatological mean field. We consider the analyzed climatological mean field on a 1° grid as a superior best guess to the zonal average and used each 1° climatological mean field as the first-guess in the corresponding 1/4° climatological analysis. For example the January 1° climatological temperature analysis was used as first-guess for the 1/4° climatological mean. The climatological value from a 1° gridpoint was assigned to the sixteen 1/4° gridpoints contained therein. For those 1/4 ° gridpoints defined as ocean where there was no 1° analyzed mean value (because the 1° gridpoint was defined as land or below ocean bottom), the analyzed mean value from the nearest 1° gridpoint not defined as land or below ocean bottom was used. The greater resolution provided by the 1/4° grid allows for more sharply defined ocean subareas. The first-guess field for the 1/4° grid must be consistent with the more sharply defined ocean subareas. When a 1° grid square contained 1/4° grid squares from more than one subarea, only the 1/4° grid squares from the most representative subarea were assigned the first-guess value from the 1° grid square. The remaining 1/4° grid squares were assigned the analyzed mean value from the closest 1° grid square from within their own ocean subarea.

The smaller grid size used for the 1/4° grid calculations resulted in more noise in the climatological mean fields as compared to the fields calculated on the 1° grid. To remove some of this noise, the monthly climatological mean fields were further smoothed by reconstructing the fields using the annual mean and the first three harmonics from a fourier analysis of the twelve monthly climatological mean fields for temperature and salinity. The resultant 12 monthly fields, from the surface to 1500 meters, were averaged to provide the mean annual climatological mean field to this depth. The appropriate three monthly fields from the surface to 1500 meters were averaged to provide the final mean fields for each seasonal climatological mean field. Below 1500 meters, the four seasonal climatological mean fields were averaged to yield the final mean annual climatological field for all standard depths down to 5500 meters. The seasonal climatological mean fields below 1500 meters (to 5500 meters depth) had no further smoothing applied. The last step was to stabilize each temperature and salinity field with respects to their calculated density field. The stabilization process is a modification of the method proposed by Jackett and McDougal [1995] and is discussed in detail in Appendices A and B.

The method for preparing the measured data for the objective analysis procedure was also basically the same as outlined in WOA01t and WOA01s. All measurements excluded from the 1° mean calculations based on checks against the standard deviation and based on subjective checks were also excluded from the 1/4° mean calculations. No further checks against standard deviation were performed at the 1/4° grid level. Further subjective checks were necessary, as the smaller area over which means were calculated revealed many more problematic data. Once the subjective checks were performed, the 1° mean calculation and objective analysis procedures were rerun excluding data found in the subjective checks on the 1/4° grid. Then the 1/4° mean calculation and objective analysis were rerun until no more removal of data due to subjective checks was necessary.

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Appendix A: Method for Dealing with Instabilities. Back to methods

1. Defining and identifying instabilities

The first step is to identify the instabilities. We use the Hesselberg-Sverdrup criteria described by Lynn and Reid (1968) and Neumann and Pierson (1966), The stability, **E,** is defined as

$$E = \underset{\partial z \to 0}{\textbf{limit}} \frac{1}{\rho_0} \frac{\delta\rho}{\partial z}$$

in which

z = depth,
ρ = *in-situ density*,
$\rho_0 = 1.02$ g cm$^{-3,}$, and
$\delta\rho$ = vertical density difference.

As noted by Lynn and Reid, the term is " the individual density gradient defined by vertical displacement of a water parcel (as opposed to the geometric density gradient). For discrete samples, the density difference ($\delta\rho$) between two adjacent levels is taken after one is adiabatically displaced to the depth of the other."

The computational form for **E** involves computing the local potential density of the deeper of the two adjacent levels with respect to the depth of the shallower of the two adjacent levels (ρ_k(**k+1**)). If this density is lower than the *in-situ* density at the higher level (σ(**k**)), this represents an instability. A profile of **E** is generated from the profiles of objectively analyzed temperature and salinity for each ocean grid box. There will be **K-1** values of **E** in the profile, where **K** corresponds to the number of depth levels at a given gridpoint.

If an instability is encountered between two levels, **k** and **k+1**, it must be determined whether to change the temperature and/or salinity to achieve stability, and whether to make the change on level **k** or level **k+1**. The goal is to change the original profiles of temperature and salinity, and by extension, of density, as little as possible while achieving stability.

2. Deciding to change temperature and or salinity

Before deciding which level to change, the values of $\Delta T/\Delta z$ and $\Delta S/\Delta z$, the gradients of temperature and salinity between adjacent levels involved in the instability, are examined. This helps determine if the temperature or salinity profile, or both, are to be changed to stabilize the density field. The values of $\Delta T/\Delta z$ and $\Delta S/\Delta z$ are in different units, but some judgements can be made looking at the sign of the values:

If $\Delta T/\Delta z > 0$, $\Delta S/\Delta z > 0$: only temperature is changed.

If $\Delta T/\Delta z < 0$, $\Delta S/\Delta z < 0$: only salinity is changed.
If $\Delta T/\Delta z > 0$, $\Delta S/\Delta z < 0$: local linear trend test employed as described in section 3.

Increasing temperature acts to decrease density (when temperature is above the temperature of the maximum density for the given salinity), decreasing salinity acts to decrease density. If temperature increases while salinity between levels is static or increasing, we assume it is the temperature gradient which is responsible for the instability between these two levels. Conversely, if the salinity is decreasing, while the temperature is static or decreasing, we assume it is the temperature data which is responsible for the noted instability. In the example in appendix B, instabilities #1, #2.2, #2.3, #5, #6, and #6.1 are stabilized using the results of this gradient test.
If temperature is increasing while salinity is decreasing between levels, more information is necessary to understand to what extent temperature and salinity are involved in creating the given instability, as we describe in the next section.

3. Local linear trend in density

A method we term the "local linear trend in density" is employed. This method is illustrated in instability #2 in the example in appendix B. In this method, the levels **k-2** to **k+3** from the temperature and salinity profiles at the grid-point containing the instability are used, where **k** is the upper level involved in the density instability and **k+1** is the deeper level. The change in density due to temperature (holding salinity constant) and the change in density due to salinity (holding temperature constant) are estimated for each set of adjacent levels [(**k-2**,**k-1**), (**k-1**,**k**), (**k**,**k+1**), (**k+1**,**k+2**), (**k+2**,**k+3**)]. The constant values of temperature and salinity used are the average values of these parameters over their entire profiles at the grid-point containing the instability.

The density change due to temperature (salinity) between levels **k** and **k+1** is used as a base value from which the density change due to temperature (salinity) between the other four sets of adjacent levels are subtracted:

$$LLT(T) = (\Delta\sigma(T)/\Delta z)_{k,k+1} - (\Delta\sigma(T)/\Delta z)_{k-2,k-1} - (\Delta\sigma(T)/\Delta z)_{k-1,k} - (\Delta\sigma(T)/\Delta z)_{k+1,k+2} - (\Delta\sigma(T)/\Delta z)_{k+2,k+3}$$
$$LLT(S) = (\Delta\sigma(S)/\Delta z)_{k,k+1} - (\Delta\sigma(S)/\Delta z)_{k-2,k-1} - (\Delta\sigma(S)/\Delta z)_{k-1,k} - (\Delta\sigma(S)/\Delta z)_{k+1,k+2} - (\Delta\sigma(S)/\Delta z)_{k+2,k+3}$$

This localized linear trend gives some sense of how the temperature and salinity are changing in the general vicinity of the instability in similar units, and how that change is affecting the density structure. For instance, if $(\Delta\sigma(T)/\Delta z)_{k,k+1} < 0$ by only a small amount, and $(\Delta\sigma(T)/\Delta z)_{k-2,k-1}$, $(\Delta\sigma(T)/\Delta z)_{k-1,k}$, $(\Delta\sigma(T)/\Delta z)_{k+1,k+2}$, and $(\Delta\sigma(T)/\Delta z)_{k+2,k+3}$ are also < 0, it would appear that the temperature is naturally increasing in the vicinity of the instability and the value of LLT(T) would reflect this by being positive, or only slightly negative. Conversely, if the base $(\Delta\sigma(S)/\Delta z)_{k,k+1} < 0$, while $(\Delta\sigma(S)/\Delta z)_{k-2,k-1}$, $(\Delta\sigma(S)/\Delta z)_{k-1,k}$, $(\Delta\sigma(S)/\Delta z)_{k+1,k+2}$, and $(\Delta\sigma(S)/\Delta z)_{k+2,k+3}$ are all > 0, this would indicate the possibility that $(\Delta\sigma(S)/\Delta z)_{k,k+1}$ may be an anomaly, and the salinity may be the source of the instability. The resultant negative LLT(S) makes this apparent.

So,

If LLT(T) < 0, LLT(S) > 0 : only temperature changed
If LLT(T) > 0, LLT(S) < 0 : only salinity changed.

If LLT(T) < 0, LLT(S) < 0 (or LLT(T) > 0, LLT(S) > 0) : combined linear trend test employed.

The combined linear trend test, which is employed in instabilities #4, #4.1, and #4.2 of the example in appendix B, is as follows:

Tp= LLT(T)/(LLT(T)+LLT(S))*100
Sp= LLT(S)/LLT(T)+LLT(S))*100

Where Tp is percent of change in density due to temperature and Sp is percent of change in density due to salinity

In this case, temperature and salinity are both change. The change in salinity is responsible for Sp percent of the total change in density needed to achieve stability. The change in temperature is made to account for Tp percent of the total change in density needed to achieve stability.

How temperature and salinity are changed

Once it is determined which variable to change, it is simple to make the change. If the upper level needs to be adjusted, the temperature is increased and/or the salinity is decreased to come as close as possible to $\rho_k(\mathbf{k+1}) - \sigma(\mathbf{k}) = 0$. This the minimum static stability. It is not always possible to reach zero exactly due to the precision limitations of the temperature and salinity values used. The distributed ASCII versions of the temperature and salinity climatologies has four digits to the right of the decimal. So, the maximum significant digits to the right of the decimal for density is also four. As a result, the minimum value for the quantity $\rho_k(\mathbf{k+1}) - \sigma(\mathbf{k})$ $<= |10^{-4}|$. If the lower level needs to be adjusted, the temperature at this level is decreased and/or salinity is increased to reach the minimum static stability. Deciding whether the upper or lower level should be changed is addressed in the next section. Since $\rho_k(\mathbf{k+1})$ is calculated using potential temperature relative to the upper level, it is actually the potential temperature which meets the $\rho_k(\mathbf{k+1}) - \sigma(\mathbf{k}) = 0$ requirement, and then from this, the *in situ* temperature is determined.

In the case where both the temperature and salinity are changed, temperature is changed first. If the upper level is being adjusted, the temperature which fits the density $\sigma(\mathbf{k})'$, (where $\sigma(\mathbf{k})' = \sigma(\mathbf{k}) - ((\rho_k(\mathbf{k+1}) - \sigma(\mathbf{k})) * (Tp/100)))$ is calculated. That is, the temperature which changes the density of the upper level Tp percent of the total change in density which is necessary to achieves stability. This temperature is then used to calculate the salinity which achieves minimum static stability.

Similarly, if the lower level is changed, the temperature which fits the density $\rho_k(\mathbf{k+1})' = \rho_k(\mathbf{k+1}) + ((\rho_k(\mathbf{k+1}) - \sigma(\mathbf{k})) * (Tp/100))$ is calculated, and then the salinity which, coupled with this temperature approaches $\rho_k(\mathbf{k+1}) - \sigma(\mathbf{k}) = 0$, is found.

The temperature is calculated by adding or subtracting small increments to the original temperature until the desired density is approached as closely as possible. The salinity is approximated using the polynomial approximation to the International Equation of State (Levitus and Isayev, 1992) from the given density and temperature, and adding or subtracting small increments until the desired density is approached as closely as possible.

Deciding on changing either upper or lower level

The temperature and/or salinity at only one level need to be changed to achieve static stability (all non-negative values in the **E** profile). The temperature/salinity change is made at the level which will least affect the overall profiles of temperature and salinity. Both the necessary change at the upper level (**k**) only and the change at the lower level (**k+1**) only are calculated. The possible new temperature and/or salinity values at the upper level(**k**) are used to calculate a new **E** value between the upper level (**k**) and the next higher (**k-1**) level (when possible) to see if a new instability is created. Likewise, a new **E** value between the lower level and the next lower level (**k+2**, when possible) is calculated from the proposed new temperature and/or salinity values. If there is a new instability created by changing the upper level, but no new instability created by changing the lower level, the lower level is the level where the temperature and/or salinity changes will be implemented, and vice-versa.

If there are new instabilities in both cases, successively higher levels are checked using the proposed temperature/salinity changes to the upper level involved in the instability, calculating **E** between the successively higher levels and the upper level with the temperature/salinity changes. The same is done between the lower level with its proposed temperature/salinity values and each successive lower level. This continues one step past either reaching the topmost level or the bottommost level. For instance, if there are nine levels in a profile, and the instability takes place between levels five and six, the proposed temperature/salinity changes to level five and to level 6 will be checked a maximum of four times for new instabilities. **E** will be calculated between the lower level and levels seven, eight, and nine, respectively. E will be recalculated between the upper level and levels four, three, two, and one. If there are instabilities all the way to the bottom, this would be equal to instabilities all the way up the water column, to level two. One more check on the upper levels is made, and if this too is an instability, this will be deemed as the upper level proposed temperature/salinity changes creating more instabilities than the lower level proposed temperature/salinity changes, and the temperature and salinities changes to the lower level will be implemented. This test was implemented in all cases in appendix B, except instabilities #2.1 and #5.

If no new instabilities are created, or if the same number of new instabilities are created in both the upper level proposed temperature/salinity changes and the lower level proposed temperature/salinity changes, the smallest necessary change is preferred.

Let |dt(**k**)| = temperature adjustment to level **k** (absolute value of original temperature value minus adjusted temperature value.
|ds(**k**)| = salinity adjustment to level **k** (absolute value of original salinity value minus adjusted salinity value).

If |dt(**k**)| < |dt(**k+1**)| and |ds(**k**)| < |ds(**k+1**)| : change **k** (upper level)
If |dt(**k**)| > |dt(**k+1**)| and |ds(**k**)| > |ds(**k+1**)| : change **k+1** (lower level)
If |dt(**k**)| > |dt(**k+1**)| and |ds(**k**)| < |ds(**k+1**)| or
|dt(**k**)| < |dt(**k+1**)| and |ds(**k**)| > |ds(**k+1**)| : use adjusted linear trend test
The above test was implemented in examples #2.2 and #5 in appendix B, but only for the trivial case in which only temperature was changed.
The adjusted linear trend (which is not demonstrated in appendix B) is as follows:

The local linear trend in density is computed for temperature and salinity for the case of the change to the upper level (**k**) and the case of the change to the lower level (**k+1**). Then the complete adjusted linear, LLTA, is

LLTA(**k**) = abs[(LLT(T(**k**)+dt(**k**))) + LLT(S(**k**)+ds(**k**)))) - (LLT(T(**k**)+LLT(S(**k**)))]

If LLTA(**k**) < LLTA(**k+1**) : change **k** (upper level)
If LLTA(**k**) >= LLTA(**k+1**) : change **k+1** (lower level)

In other words, the level that is changed is the level which minimizes total change to local linear trends of density with respects to temperature and salinity. In the case where the change is equal, the choice of level to change is ambiguous and the level changed is arbitrarily set to the lower level.

Finalizing temperature and salinity profiles

Each **E** profile is checked for instabilities starting at the surface and then proceeding to the bottom, or the thirty-third standard level (5500 meters), whichever is reached first. If an instability is encountered, it is dealt with as detailed above. If this process results in a new instability involving the upper layer involved in the old instability and the level above that one, this new instability is dealt with before proceeding further down the profile. This process is continued until there are no instabilities in the entire **E** profile. It may be that the temperature and salinity at a level are changed numerous times in the process of stabilizing the entire **E** profile. This may be necessary to achieve the minimum possible changes over the entire temperature and salinity profiles while still creating stability.

Then the procedure is performed again on the original **E** profile, this time starting from the bottom of the profile and continuing to the surface. There are grid boxes which have large gradients in temperature and/or salinity near the surface. If these large gradients are involved in an instability, and the **E** profile is being checked from the top down, these large gradients may propagate changes down to lower depths when they should be confined to the upper depths. When the profile is checked from the bottom up, the lower depths are usually preserved intact while changes are made only in the upper layer.

Finally, the density change due to temperature and to salinity is calculated for the top- down and the bottom-up cases. The density change from the original profile due to temperature is calculated at each level, as is the density change from the original profile due to salinity.

The density changes at each level are added together and divided by the number of levels minus one to get an average density change for both the top-down case and the bottom-up case. The case with the lowest average density change is the case implemented. If average density change is equal in both cases, the top down case is implemented.

Appendix B: Example of Stabilization. Back to methods

The area chosen for this example is the one degree latitude-longitude box centered at 53.5°S - 171.5°E. This is on the New Zealand Plateau, with a bottom depth below 1000 meters and above 1100 meters. The month is October, during the early austral summer. There is a deep mixed layer in this area, using vertical temperature change as an indicator. There is no temperature or salinity data within the chosen one-degree box. Thus the objectively analyzed values in this one-degree box will be dependent on the seasonal objectively analyzed field and the data in near-by one-degree grid boxes. There is much more temperature data than salinity data on the New Zealand plateau for October. This contributes to 6 small (on the order of 10^{-2} kg/m^3) inversions in the local potential density field calculated from objectively analyzed temperature and salinity fields. The whole numbers in bold below correspond to the numbered instability shown in Table 1a and Table 1b. The decimal numbers in bold shown in Table 1b correspond to new instabilities created while correcting the original instabilities. Table 1b shows the final, stabilized profiles.

#1 Working first from the bottom of the profile upwards, the first inversion is encountered between 400 and 500 meters depth. The temperature rises with the increase in depth here, from 6.8275°C to 7.4001°C, while the salinity increases from 34.2852 PSS to 34.3123 PSS. Using the criteria of the gradient test, the temperature will be changed here, while the salinity will not. Now it remains to decide whether to change the temperature value at 400 m. or 500 m. If the temperature value at 400 m. is changed to eliminate the instability, a new instability will be created between 300 m. and 400 m. depth. No new instability is created if the value at 500 m. depth is changed. Therefore the temperature value at 500 m. depth is changed to 6.9838 to create a situation where the stability is within 10^{-4} kg/m^3 of neutral stability.

#2 Continuing upwards, the next instability is found between 250 and 300 m. depth. The temperature here rises from 7.0962°C to 7.1622°C. The salinity decreases from 34.3415 PSS to 34.3367 PSS. The gradient test can not be used in this case, since both temperature and salinity are acting to decrease stability. The next test, the local linear trend in density must be implemented. This test ascertains the general tendency of the temperature and salinity in the immediate area of the instability. Is the temperature generally increasing? Is the salinity generally increasing? In this case, the levels to be checked, listed by depths are:

k-2 = 150 m. depth, t(**k-2**) = 6.8919°C, s(**k-2**) = 34.3697 PSS (instability)
k-1 = 200 m. depth, t(**k-1**) = 6.9363°C, s(**k-1**) = 34.3364 PSS (instability)
k = 250 m. depth, t(**k**) = 7.0962°C, s(**k**) = 34.3415 PSS(instability)
k+1 = 300 m. depth, t(**k+1**) = 7.1622°C, s(**k+1**)= 34.3367 PSS
k+2 = 400 m. depth, t(**k+2**) = 6.8275°C, s(**k+2**)= 34.2852 PSS
k+3 = 500 m. depth, t(**k+3**) = 6.9838°C, s(**k+3**)= 34.3123. PSS

It is already known that the changes in both temperature and salinity between **k** and **k+1** work to decrease stability, otherwise, this test would not be needed. Therefore the density change between levels **k** and **k+1** keeping salinity constant is negative. The test is to see how large is the density change between levels **k** and **k+1** in relation to the cumulative density changes between other adjacent levels, keeping salinity constant. The density changes between levels **k-2** and **k-1**, and between levels **k-1** and **k** are not used in this test for this case because the density structure between these adjacent levels are unstable and therefore assumed to include anomalous temperature and/or salinity values. The density change due only to temperature between levels **k+1** and **k+2** is positive and fairly large in comparison with the instability between **k** and **k+1**. The density change between levels **k+2** and **k+3** is negative. However, the cumulative valid density changes due only to temperature between adjacent levels in the immediate area of the instability between levels **k** and **k+1** is positive and slightly larger in comparison with the absolute value of the instability between levels **k** and **k+1**. To get a numerical value for this comparison, the cumulative value of valid density changes due to temperature between adjacent levels in the immediate area of the instability between levels **k** and **k+1** is subtracted from the value of the density change between levels **k** and **k+1**. If the result is positive, this denotes that the gradient of the temperature in the immediate area of the instability is of the same sign as the temperature gradient between levels **k** and **k+1**. This reinforces the idea that the temperature gradient between levels **k** and **k+1** is probably not an anomaly, but follows the true pattern of the temperature profile. If the result is negative, this denotes that the temperature gradient between levels **k** and **k+1** does not follow the pattern of adjacent areas of the temperature profile and is probably an anomaly.

Looking at the change in density between adjacent levels due to salinity, the change between levels **k+1** and **k+2** is quite large in comparison to the density change due to salinity between the levels **k** and **k+1**, where the instability occurs. The change between levels **k+2** and **k+3** in density due to salinity is negative and smaller in absolute value than the increase between levels **k+1** and **k+2**.

The results for the local linear trend test in density for temperature and salinity are negative and positive respectively. These results lead to a change in temperature in either level **k** or level **k+1** to rectify the instability. This is not the optimal trial for the local linear trend in density test because two of the four adjacent level density changes could not be used due to their own instabilities. If either the upper (**k**) value for temperature or lower (**k+1**) value is changed, new instabilities will result in the profile. In the case where instabilities already exist, (the upper level temperature value changed) the instabilities are exacerbated. But more levels will be affected if the upper level temperature value is changed. So the lower level (**k+1**) temperature value is changed to eliminate the instability between levels **k** and **k+1**. The new value at 300 m. depth for temperature is 7.0748C°.

#2.1,#2.2 Because of this change, there is now an instability between 300 and 400 m. depth. The gradient test reveals negative gradients in temperature and salinity. This leads to a new salinity value of 34.2894 PSS (from an old value of 34.2852 PSS) at 400 m. depth. Temperature is unchanged. This causes a new instability between 400 and 500 m. depth. The gradient test indicates a change only to temperature. Since neither a change to the upper level or lower level will cause new instabilities, a temperature change to the lower level is implemented because it incurs a smaller change to the temperature at that level than would the change to the upper level. The new temperature value at 500 m. depth is 6.9604°C (old value 6.9838°C).

#3 Since no new instabilities were created in the last change, checking proceeds up the profiles again. The next instability occurs between 200 and 250 m. depth. The result of the gradient test and choosing the minimum change to the original values, is to change the temperature only, at 200 m. depth, from 6.9363°C to 7.0628°C.

#4 The instability between 150 and 200 m. depth cannot be resolved using the gradient test. The following levels are set for the local linear trend in density test:

k-2 = 100 m. depth, t(**k-2**) = 6.9753°C, s(**k-2**) = 34.3280 PSS
k-1 = 125 m. depth, t(**k-1**) = 6.9218°C, s(**k-1**) = 34.3604 PSS
k = 150 m. depth, t(**k**) = 6.8919°C, s(**k**) = 34.3697 PSS (instability)
k+1 = 200 m. depth, t(**k+1**) = 7.0628°C, s(**k+1**)= 34.3364 PSS
k+2 = 250 m. depth, t(**k+2**) = 7.0962°C, s(**k+2**)= 34.3415 PSS
k+3 = 300 m. depth, t(**k+3**) = 7.0748°C, s(**k+3**)= 34.3367 PSS.

Since this is an iterative process, the values for temperature at 250 and 300 m. depth are the newly calculated values, not the original values.

In this case, the density with respects to temperature increases between levels **k-2** and **k-1**, between **k-1** and **k**, and between **k+2** and **k+3**. This is not completely offset by the decrease in density due to temperature between levels **k+1** and **k+2**. So the numerical value for temperature for the local linear trend in density is negative. For density with respects salinity, the value is positive for all adjacent levels except between **k+2** and **k+3**. The local linear trend in density for salinity is also negative. So this test is also inconclusive.

When this point is reached, both temperature and salinity will be changed. The extent to which they will be changed depends on their relative local linear trends in density. This is the reason for computing the local trends of temperature and salinity in like units. The local linear trend in density for temperature is -0.0357 kg/m^3. The local linear trend in density for salinity is -0.0592 kg/m^3. Using their ratio, 62% of the change in density necessary for stabilization will be accounted for by changing the salinity, 38% will be accounted for by changing the temperature. Changes on the upper level are found to cause fewer new instabilities than changes to the bottom level. The new values for 150 m. depth are 7.0242°C for temperature and 34.3301 PSS for salinity.

#4.1 A new instability is created between 125 and 150 m. depth. Again, both the gradient test and the local linear trend in density are inconclusive. Both temperature and salinity are changed, with salinity accounting for 75% of the change in density. The values at 125 m. depth are changed from 6.9218°C to 6.9897°C for temperature and 34.3604 PSS to 34.3243 PSS for salinity.

#4.2 A new instability between 100 and 125 m. depth is again resolved only by changing both temperature and salinity at 100 m. The new values are 6.9796°C and 34.3228 PSS for the respective variables (old values 6.9753°C and 34.3280 PSS).

#5, #6, #6.1 The final two original instabilities, between 50 and 75 m. depth and between 10 and 20 m. depth are both resolved by the gradient test. The level of the change for the former instability is chosen on the basis of least change to the temperature, since no new instabilities are created. In this case the value of temperature at 50 m. depth is changed from 6.9686°C to 7.0132°C. For the later case, the value of salinity at 10 m. depth is changed from 34.4278 PSS to 34.3063 PSS. This creates one last instability between the surface and 10 m. depth. The gradient test yields a change in the surface salinity from 34.4243 PSS to 34.3096 PSS. The level at which the change is made is based on the change which creates the fewest new instabilities.

A complete, altered, stable set of temperature and salinity profiles has now been achieved.

The entire process is repeated starting from the top and proceeding downwards through the profile. The changes to density at each level are calculated for the results of the top-down and bottom-up calculations. The procedure which cumulatively changes the original density structure least is chosen as the final result. The reason for doing both top-down and bottom-up procedures is that when there is a large instability near the surface, doing the top-down procedure can significantly alter the entire profile set, whereas bottom-up will confine the changes to the near surface portion. The converse is also true. So both procedures are performed to identify the procedure which changes the original the least.

The chosen profile is an extreme example of the stabilization process, used to illustrate all aspects of the procedure. Each instability is initially treated separately, and a single level in a profile may be altered many times due to changes in the surrounding levels before a fully stable set of temperature and salinity profiles is produced.

Table 1a Gridbox 171.5°E, 53.5°S Improved WOA98 profiles before stabilization. Back to methods

Depth (m)	Temp (°C)	Salinity	ρ (kg/m^3)	ρ (kg/m^3)	**E** (kg/m^3)	Change #
0.0	7.1667	34.4243	26.9423	26.9476	0.0054	
10.0	7.1489	34.4278	26.9939	26.8982	-0.0957	**#6**
20.0	7.0465	34.2880	26.9443	26.9529	0.0085	
30.0	7.0050	34.2914	26.9990	27.0104	0.0114	
50.0	6.9686	34.2991	27.1028	27.0967	-0.0061	**#5**
75.0	7.0604	34.3073	27.2120	27.2406	0.0286	
100.0	6.9753	34.3280	27.3560	27.3892	0.0332	
125.0	6.9218	34.3604	27.5046	27.5164	0.0117	
150.0	6.8919	34.3697	27.6316	27.6000	-0.0316	**#4**
200.0	6.9363	34.3364	27.8302	27.8123	-0.0179	**#3**
250.0	7.0962	34.3415	28.0421	28.0295	-0.0126	**#2**
300.0	7.1622	34.3367	28.2593	28.2684	0.0092	
400.0	6.8275	34.2852	28.7281	28.6664	-0.0618	**#1**
500.0	7.4001	34.3123	29.1238	29.3699	0.2461	
600.0	6.2133	34.4022	29.8292	29.9386	0.1094	
700.0	5.9186	34.4868	30.3978	30.5869	0.1891	
800.0	4.5426	34.4904	31.0488	31.0754	0.0266	
900.0	4.1263	34.4558	31.5377	31.6539	0.1162	
1000.0	3.3112	34.4755	32.1176			

Table 1b Gridbox 171.5°E, 53.5°S Improved WOA98 profiles after stabilization **Back to methods**

Depth (m)	Temp (°C)	Salinity	ρ (kg/m^3)	ρ (kg/m^3)	**E** (kg/m^3)	Change #
0.0	7.1667	34.3096	26.8519	26.8521	0.0002	**#6.1**
10.0	7.1489	34.3063	26.8982	26.8982	0.0000	**#6**
20.0	7.0465	34.2880	26.9443	26.9529	0.0085	
30.0	7.0050	34.2914	26.9990	27.0042	0.0051	
50.0	7.0132	34.2991	27.0967	27.0967	0.0000	**#5**
75.0	7.0604	34.3073	27.2120	27.2361	0.0240	
100.0	6.9796	34.3228	27.3513	27.3513	0.0000	**#4.2**
125.0	6.9897	34.3243	27.4667	27.4667	0.0000	**#4.1**
150.0	7.0242	34.3301	27.5820	27.5820	0.0000	**#4**
200.0	7.0628	34.3364	27.8123	27.8123	0.0000	**#3**
250.0	7.0962	34.3415	28.0421	28.0422	0.0000	**#2**
300.0	7.0748	34.3367	28.2719	28.2719	0.0001	**#2.1**
400.0	6.8275	34.2894	28.7314	28.7314	0.0000	**#1, #2.2**
500.0	6.9604	34.3123	29.1899	29.3699	0.1799	
600.0	6.2133	34.4022	29.8292	29.9386	0.1094	
700.0	5.9186	34.4868	30.3978	30.5869	0.1891	
800.0	4.5426	34.4904	31.0488	31.0754	0.0266	
900.0	4.1263	34.4558	31.5377	31.6539	0.1162	
1000.0	3.3112	34.4755	32.1176			