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OBJECTIVE ANALYSES OF ANNUAL, SEASONAL, AND MONTHLY TEMPERATURE AND SALINITY FOR THE WORLD OCEAN ON A 0.25° GRID

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ABSTRACT

Objectively analysed climatological mean fields of temperature and salinity have been calculated on a 0.25° grid for the World Ocean for the annual, seasonal, and monthly compositing periods using data from the *World Ocean Database 2001*. The annual and seasonal fields are calculated at standard levels from the surface to 5500 m. The monthly fields are calculated at standard levels from the surface to 1500 m. In comparison with similarly computed climatologies calculated on a 1° grid, ocean circulation features, such as the Gulf of Mexico Loop Current, are more clearly represented. The new 0.25° climatologies preserve most of the spatial resolution of earlier 0.25° temperature and salinity climatologies, while reducing noise by additional smoothing in horizontal space (geographically at each depth), vertically (along depth at each grid), as well as in time (Fourier filtering). Copyright © 2005 Royal Meteorological Society.

KEY WORDS: ocean temperature; salinity; climatology

1. INTRODUCTION

The temperature and salinity climatologies presented as part of the *Climatological Atlas of the World Ocean* (Levitus, 1982) and its atlas updates in 1994 (Levitus and Boyer, 1994; Levitus *et al*., 1994), 1998 (Antonov *et al*., 1998a–c; Boyer *et al*., 1998a–c), and 2001 (Stephens *et al*., 2002 (hereafter referred to as W01t for the temperature analyses); Boyer *et al*., 2002 (hereafter referred to as W01s for the salinity analyses); referred to as W01 collectively) have proven to be valuable tools for studying the temperature and salinity structure of the World Ocean, including uses as initial and boundary conditions for ocean circulation models and for validating ocean remote sensing data, such as altimetric measurements of sea level. The main improvement of the atlas updates released since 1982 has been the addition of significant amounts of data assembled from international data management projects including the Intergovernmental Oceanographic Commission (IOC) sponsored Global Ocean Data Archeology and Rescue (GODAR) project, the World Ocean Database project (Conkright *et al*., 2002; Levitus *et al*., 2005), the MEDAR/MEDATLAS project sponsored by the European Community, as well as routine international ocean data exchange carried out under the auspices of the IOC. We have received requests for climatological fields on isobaric surfaces with resolution greater than 1°, which has motivated the work described in this paper. Climatologies of surface marine properties are generally computed on grids with at maximum 1° resolution. Our new high 0.25° climatologies document improvements that result from this increased resolution.

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All of the above climatological mean fields were calculated on a 1° latitude/longitude grid. Boyer and Levitus (1997) calculated 'all-data' annual fields of climatological mean temperature and salinity on a 0.25° grid, which greatly improved the spatial resolution of these climatological fields. However, Chang and Chao (2001) noted that the Boyer and Levitus (1997) fields are quite noisy spatially. Noise, here, refers to small variations on the scale of two to five grid boxes that are an artifact of temporal and spatial discrepancies in measurement distributions rather than a true reflection of the climatological mean. The present work details the calculation of new, improved annual, seasonal, and monthly fields of climatological mean temperature and salinity on a 0.25° grid (hereafter collectively referred to as Q01) and compares the results with W01 and Boyer and Levitus (1997). The Q01 fields have increased spatial smoothing over those of Boyer and Levitus (1997), reducing noise while still preserving tight spatial gradients. Other improvements over Boyer and Levitus (1997) include the addition of significant amounts of data, the calculation of seasonal and monthly climatologies, and Fourier time filtering of the monthly climatologies.

W01 and Q01 used the same data set, the *World Ocean Database 2001* (WOD01), so the major improvement of the new 0.25° climatologies over the W01 1° climatologies is primarily due to increased spatial resolution. The 0.25° climatological fields resolve features that are not as well defined in the previous 1° analyses, such as the climatological Loop Current in the Gulf of Mexico. Also, small, isolated regions, such as the Sulu Sea, are better resolved on the high-resolution grid, so that analyses at the high resolution reflect better the regional physical property distributions of the area compared to the 1° grid fields analysed. Month-to-month and season-to-season variations in small-scale features and in small distinct oceanic regions can also be discerned better by comparison of the seasonal and monthly climatological mean fields on the 0.25° grid to their 1° counterpart fields.

Problems due to little or no data in some oceanic regions are magnified in the 0.25° grid, since a reduced area (the influence region) and hence number of data points, is used to produce an analysed value in each grid box. This drawback has been bypassed to some extent by using the 1° grid analysed climatological mean fields as first-guess fields for the 0.25° calculations. A first-guess field is a best guess of the structure of a climatological mean field. Thus, in areas with little or no data on the 0.25° grid, the 1° grid climatological field is the dominant signal.

2. METHODS

The Q01 0.25° grid climatological mean fields of temperature and salinity for the annual, seasonal, and monthly time periods were calculated using data from WOD01 using objective analysis techniques that were essentially the same as those detailed in W01t and W01s for the 1° grid climatological mean fields, with differences described below. The Q01 annual and seasonal fields were calculated at standard levels from the surface to 5500 m. The seasons are defined as 3-month periods, starting with winter defined as January, February, and March. The Q01 monthly fields were calculated at standard levels from the surface to 1500 m.

The smaller spatial resolution for Q01 increases greatly the number of temperature and salinity measurements used to calculate climatologies, even when using the same dataset as W01t and W01s. In a coastal area, a 1° grid box could be designated land when up to half of the 16 0.25° grid boxes contained within the 1° grid box are designated ocean. Since a large percentage of oceanographic data in WOD01 is near-shore data and climatologies are only calculated for grid boxes designated as ocean grid boxes, a large increase in data is available data for the 0.25° climatologies. Approximately 18% of all temperature data in WOD01 are in 1° grid boxes designated as land grid-boxes. Only 3% of all data in WOD01 are in 0.25° grid boxes designated as land grid-boxes.

Our objective analysis procedure produces estimates of climatological mean values at each grid box based on the cumulative weighted difference between the means and first-guess fields at all grid boxes within a given 'radius of influence' around the centre of a grid box. In the present case, for both 1° grid and 0.25° grid, the procedure was repeated three times, each time with a diminishing radius of influence. The reduced grid-box size for the 0.25° 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 were also reduced, so as to limit

Table I. Radii of influence on each pass through analysis procedure

Pass	Radius of influence (km)	
	1° grid (W01)	0.25° grid (Q01)
1	892	321
2	669	267
3	446	214

the number of grid boxes that would affect the climatological mean value. The sizes of the radii of influence for each pass through the analysis for each grid size are given in Table I.

For both the 1° and 0.25° cases, there are still areas of the ocean for which we have little or no data; as such, our analyses within these areas should be used with caution. We define an area as data sparse if there are ≤ 3 mean temperature (or salinity) values within the largest radius of influence around a grid box.

Another major difference between our 1° and 0.25° analyses is the degree of smoothing. The 1° climatologies were smoothed using one pass of a Shuman grid-point smoother (Shuman, 1957) followed by one pass of a gradient-preserving median smoother (Rabiner *et al.*, 1975). The median smoother uses the data from grid boxes directly to the west, east, north and south, in addition to the datum from the grid box itself. The 0.25° climatologies were smoothed using only the median smoother, but using data from five grid boxes on either side of a datum in addition to the datum itself.

The first-guess field for the 1° climatological mean fields was the 1° zonal average of all data within a subarea (e.g. Atlantic Ocean, Pacific Ocean, Mediterranean Sea, small marginal basins). As previously stated, for the 0.25° climatological analysis we used the corresponding analysed climatological mean fields on a 1° grid as the first-guess field. To do this, the climatological value from a 1° grid box was assigned to the 16 0.25° grid boxes contained therein. For those 0.25° grid boxes defined as ocean where there was no 1° analysed mean value because the 1° grid box was defined as land or ocean bottom, the analysed mean value from the nearest 1° grid box not defined as land or ocean bottom and within the same ocean basin was used. If no data existed in the ocean basin defined for the 1° analysis, then the average of all 0.25° grid mean values for the basin was used. This last situation only occurred in small deep basins, such as the northeast Sulu Sea, which is not resolved at the 1° resolution (defined as ocean bottom for the 1° analysis), but for which data does exist and there is sufficient resolution to define ocean grid boxes for this basin in the 0.25° analysis.

The increased resolution provided by the 0.25° grid allows for more sharply defined ocean subareas, so the first-guess field for the 0.25° grid must be consistent within these subareas. When a 1° grid box contained 0.25° grid boxes from more than one subarea, only the 0.25° grid boxes from the most representative subarea were assigned the first-guess value from the 1° grid box. The remaining 0.25° grid boxes were assigned the analysed mean value from the closest 1° grid box from within their own ocean subarea.

As noted previously, calculations on a 0.25° grid result in more noise in the climatological mean fields compared with fields calculated on a 1° grid. To remove some of this noise, the 0.25° monthly climatological mean fields were further smoothed by reconstructing the fields using the annual mean and the first three harmonics from Fourier analysis of the monthly climatological mean fields of temperature and salinity. The resultant 12 monthly fields, from the surface to 1500 m, were averaged at each grid box to provide the mean annual climatological mean field to this depth. The appropriate 3-monthly fields from the surface to 1500 m were averaged to provide the final mean fields for each seasonal climatological mean field. Below 1500 m, the four seasonal climatological mean fields were averaged to yield the final mean annual climatological field for all standard depths down to 5500 m. The seasonal climatological mean fields below 1500 m (to 5500 m depth) had no Fourier smoothing applied. The use of the annual mean and first three harmonics to construct monthly climatologies represents a trade-off between filtering out what we believe to be unrealistic climatological features and possibly misrepresenting the annual cycle in some regions. We chose to use three harmonics based on inspection of all Fourier components at all depth levels of the upper 1500 m of the world ocean. For temperature, the annual cycle of sea-surface temperature (SST) in parts of the North Pacific and North Atlantic oceans is sufficiently asymmetric so that the third harmonic should be included in any reconstruction. Even though this harmonic contributes less than 5% of the variance of the annual cycle, its amplitude exceeds 0.25 °C over large regions. If one were to exclude the third harmonic in a reconstruction of SST and then use the resulting monthly SST fields as a lower boundary condition to force an atmospheric general circulation model, then one might obtain spurious results. Large parts of the Southern Hemisphere show such an asymmetry, but not as coherently as in the Northern Hemisphere. We suspect that the variability of these (and higher) harmonics in the Southern Hemisphere might be related to eddy activity in these regions. Even ignoring the fourth harmonic, as we have done, might be problematic for some applications. For example, in the Northern Hemisphere regions where the third harmonic is important, we observe similar, but much smaller regions where the fourth harmonic exceeds 0.25 °C. Sea-surface salinity exhibits even more asymmetrical behaviour in some regions than does SST, particularly in regions of high river runoff such as the Bay of Bengal. For example, in the Bay of Bengal the sixth harmonic can account for more than 10% of the climatological annual signal. The problem we have is that we do not have much salinity data and we fully expect that regions of high river runoff exhibit substantial interannual-to-decadal variability. Hence, our results, and in fact any Fourier-filtered version of our fields, must be used with caution.

Our last step was to stabilize each temperature and salinity field in the vertical with respect to their calculated densities. Thus, all temperature and salinity fields yield a vertically stable density structure. The stabilization process is a modification of the method detailed by Jackett and McDougall (1995). Since density is a nonlinear function of temperature and salinity (and pressure), objectively analysing temperature and salinity separately on depth surfaces causes the relationship between temperature and salinity with respect to density to change, which can result in small instabilities between adjacent levels at some grid boxes. To rectify this problem, temperature and salinity values are minimally altered to create a nonnegative stability, $E \geq 0$, where stability E is the Hesselberg–Sverdrup criteria described by Lynn and Reid (1968) and Neumann and Pierson (1966), defined as

$$E = \lim_{\partial z \to 0} \frac{1}{\rho_0} \frac{\delta \rho}{\partial z}$$

in which z is the depth, ρ is the *in situ* density, $\rho_0 = 1020$ kg m^{-3}, and $\delta\rho$ is the individual density difference defined by adiabatic vertical displacement of a deeper water parcel to the depth of a shallower water parcel.

The method for preparing the observed data for the objective analysis procedure was basically the same as outlined in W01t and W01s. 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 0.25° mean calculations. No further checks against standard deviation were performed for the 0.25° grid. However, further quality control checks on the initial data were necessary, as the reduced area over which means were calculated revealed additional non-representative data. Once these checks were performed, and additional suspect data were flagged, the 1° mean calculation and objective analysis procedures were rerun excluding the newly flagged data. Then the 0.25° mean calculation and objective analysis were rerun until no more exclusion of data was necessary.

Here, our discussion follows that given by Levitus (1982). The weight function of Barnes (1964) is based on the principle that 'the two-dimensional distribution of an atmospheric variable can be represented by the summation of an infinite number of independent harmonic waves, that is, by a Fourier integral representation'. Any gridded field has the limitation that it takes seven or eight Δx to describe a Fourier component adequately, where Δx is the distance between adjacent grid points. So, the ideal interpolation procedure would remove all wavelengths shorter than $8\Delta x$ completely, while preserving completely all longer wavelengths. For our 1° climatologies, Δx is ~111 km at the equator, so the ideal cutoff wavelength would be 888 km. For our 0.25° climatologies, Δx is ~27.5 km, and the cutoff wavelength would be 222 km. This is a lower limit, and applies to an ideal case. Barnes (1964) derived a response function for finite objective analysis. The response function is a measure

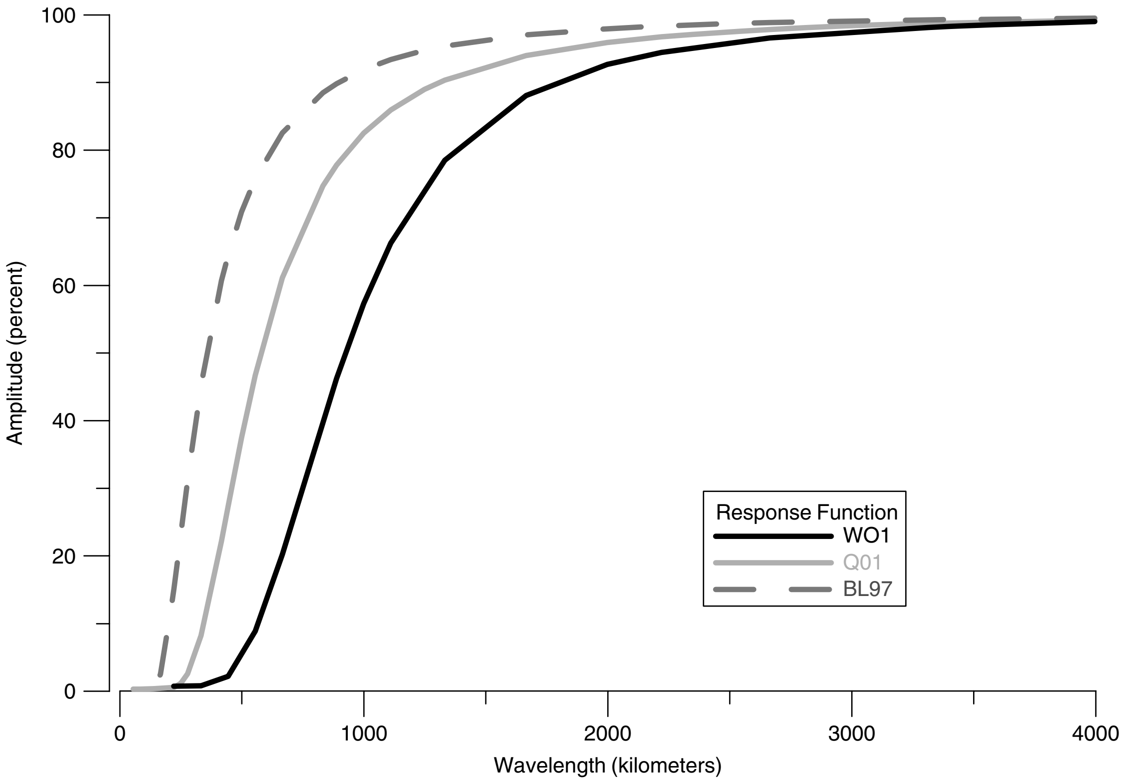

Figure 1. Response function for W01, Q01, and Boyer and Levitus (1997) (BL97) for wavelengths up to 4000 km

of the response of the data to one iteration of the interpolation procedure. Barnes's response function D is

$$\mathrm{D} = \exp(\pi^2 R^2 / 4\lambda^2)$$

for which R is the radius of influence and λ is the wavelength of a Fourier component.

The response function is dependent on the radius of influence used and we want to resolve as many wavelengths as possible (down to the ideal limit). Owing to the irregular distribution of data geographically, it is necessary to use a radius of influence large enough to contain sufficient data to interpolate meaningful climatological values. Use of multiple passes with successively smaller radii of influence, along with additional smoothing between passes, is necessary due to the irregularity of the data.

Barnes's response function is defined for one pass through the objective analysis, and does not account for any additional smoothing. To approximate the response function for our full three-pass analysis procedure with additional smoothing, we created a perfect data set of summations of only integral wavelength components on our grid. This perfect data set was then run through the analysis procedure and Fourier analysed. The resultant set of amplitudes is the response function for our analysis. The amplitudes are between zero and one and give a measure of the spatial features resolved by our analysed fields.

Figure 1 shows the response functions (wavelengths in kilometres) for the 1° fields analysed, for Boyer and Levitus (1997) and for Q01. Examining first $8\Delta x$ waves, roughly 40% (0.40) of an 888 km wave is retained in the 1° fields, whereas less than 1% (0.002) of a 222 km wave is retained in Q01. Using 60% (0.60) as a threshold beyond which we can have confidence in the spatial resolution of the given Fourier component, features of ~1110 km or greater are well resolved in our 1° analyses, while features of ~666 km or greater are well resolved in Q01. This is a significant improvement in spatial resolution between the Q01 and the W01 analyses.

3. RESULTS

We present some examples of the new 0.25° temperature and salinity climatologies to illustrate the enhanced spatial resolution of Q01 in comparison with W01t and W01s. We also compare Q01 with Boyer and Levitus (1997). The first example is on a basin scale at the surface and 100 m depth to show the similarities and differences between the climatologies at a large scale and in the upper ocean. The other examples are of smaller scale features at depths and in areas that highlight dramatic differences between climatologies. Figure 2 shows the Atlantic Ocean annual climatological temperature field at the surface and 100 m depth from W01t and

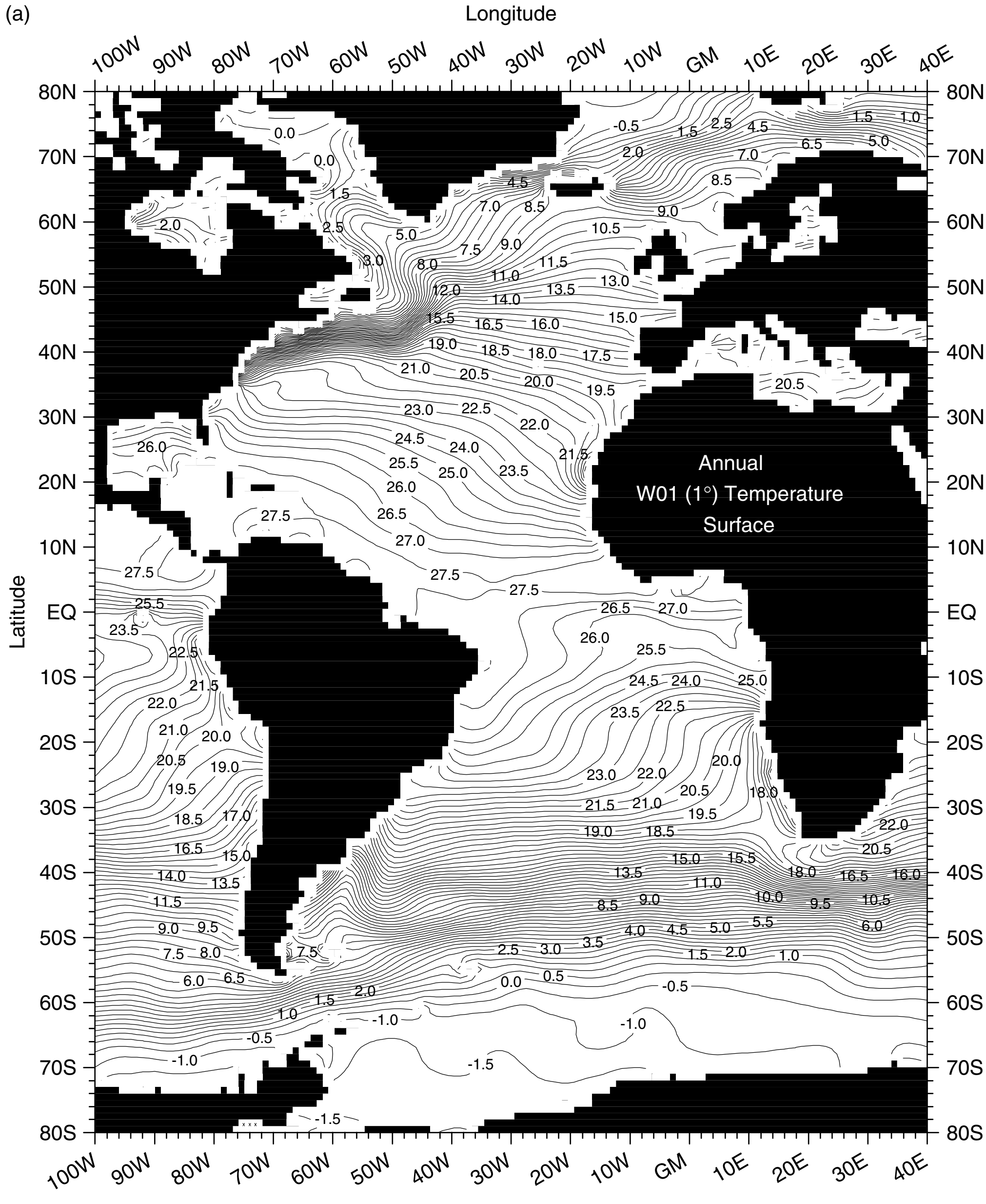

Figure 2. Atlantic Ocean mean temperatures Data-sparse grid boxes are hatched. (a) Surface from 1° annual climatology (W01t); (b) 100 m depth from 1° annual climatology (W01t); (c) surface from 0.25° annual climatology (Q01); (d) 100 m from 0.25° annual climatology (Q01)

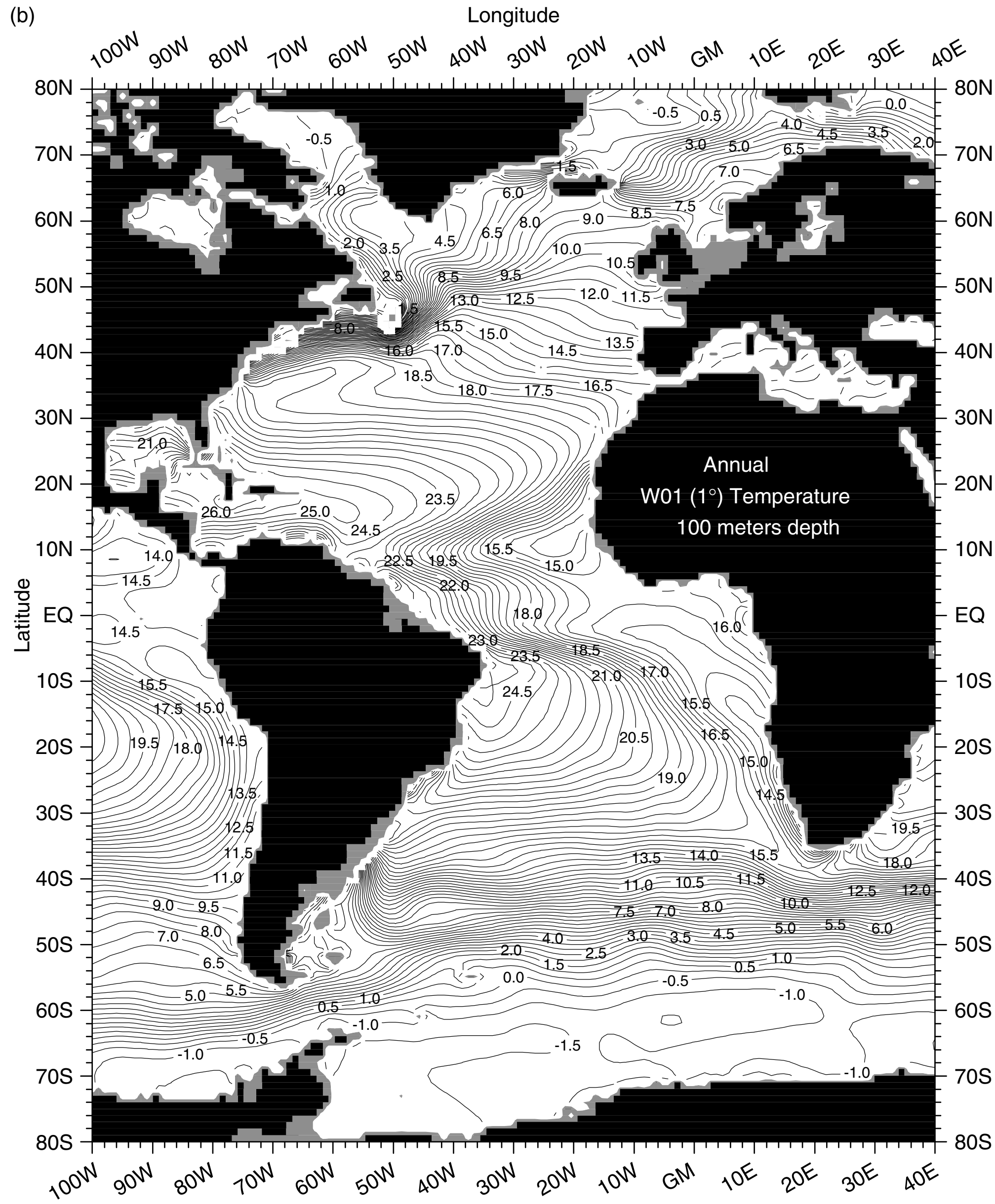

Figure 2. (*Continued*)

Q01. The large-scale patterns in the temperature field are similar in each. However, many small-scale features that are poorly defined or absent in W01t are clear and evident in Q01. For instance, the Florida Current is represented in Q01 at 100 m, but it is not fully resolved in W01t. The temperature gradients associated with the northern edge of the subpolar gyre around Greenland are smoothed out in some places in W01t, but they are clearly visible in Q01 at both the surface and 100 m. The Gulf Stream is characterized by tighter gradients in Q01. Sharper temperature gradients off the coast of Argentina and southern Africa improve upon their smoothed counterpart in W01t. Overall, many features that are smoothed out in the 1° degree climatology are better resolved in the 0.25° climatology. Data-sparse areas, which are hatched in all figures, are nonexistent in the W01t and found only in small areas of the South Atlantic in Q01 in Figure 2.

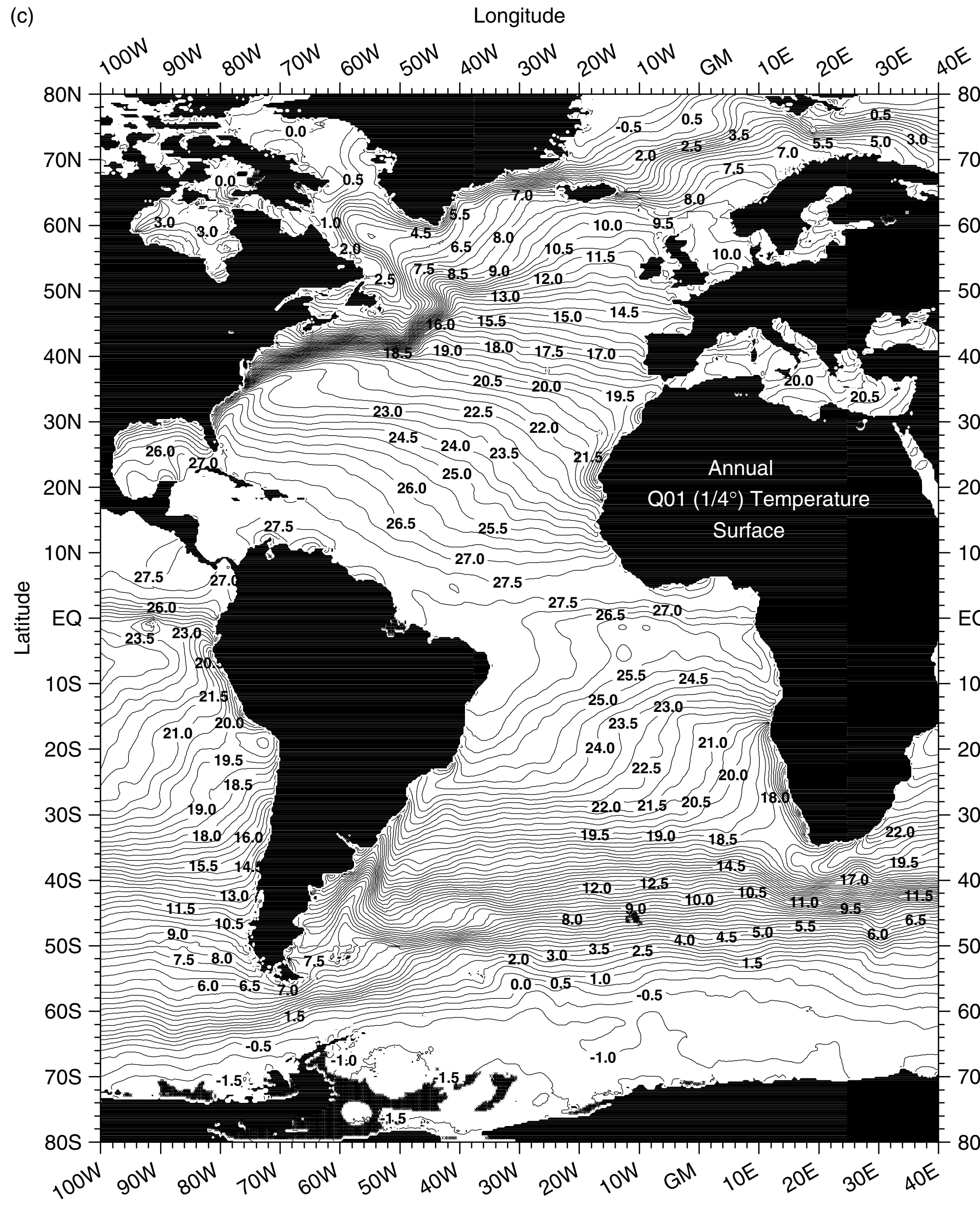

Figure 2. (*Continued*)

Q01 also offers improvements over the previous version of the 0.25° climatology (Boyer and Levitus, 1997) as demonstrated in Figure 3. Figure 3(a) shows the Agulhas Retroflection region for the W01s annual salinity climatology at 500 m depth. Figure 3(b) shows the same area for Boyer and Levitus (1997), and Figure 3(c) shows the present 0.25° climatology (Q01). Boyer and Levitus (1997) used one pass through the objective analysis with a radius of influence of 134 km. This resulted in sharp horizontal gradients, but more noise in parts of the World Ocean. This noise was cited by Chang and Chao (2001) as a problem with Boyer and Levitus (1997), but the sharp gradients were an advance over 1° climatologies. Q01 uses three passes through the objective analysis procedure, as well as additional smoothing in time and space. Our new work achieves a reasonable balance between W01s and Boyer and Levitus (1997). While the large-scale features

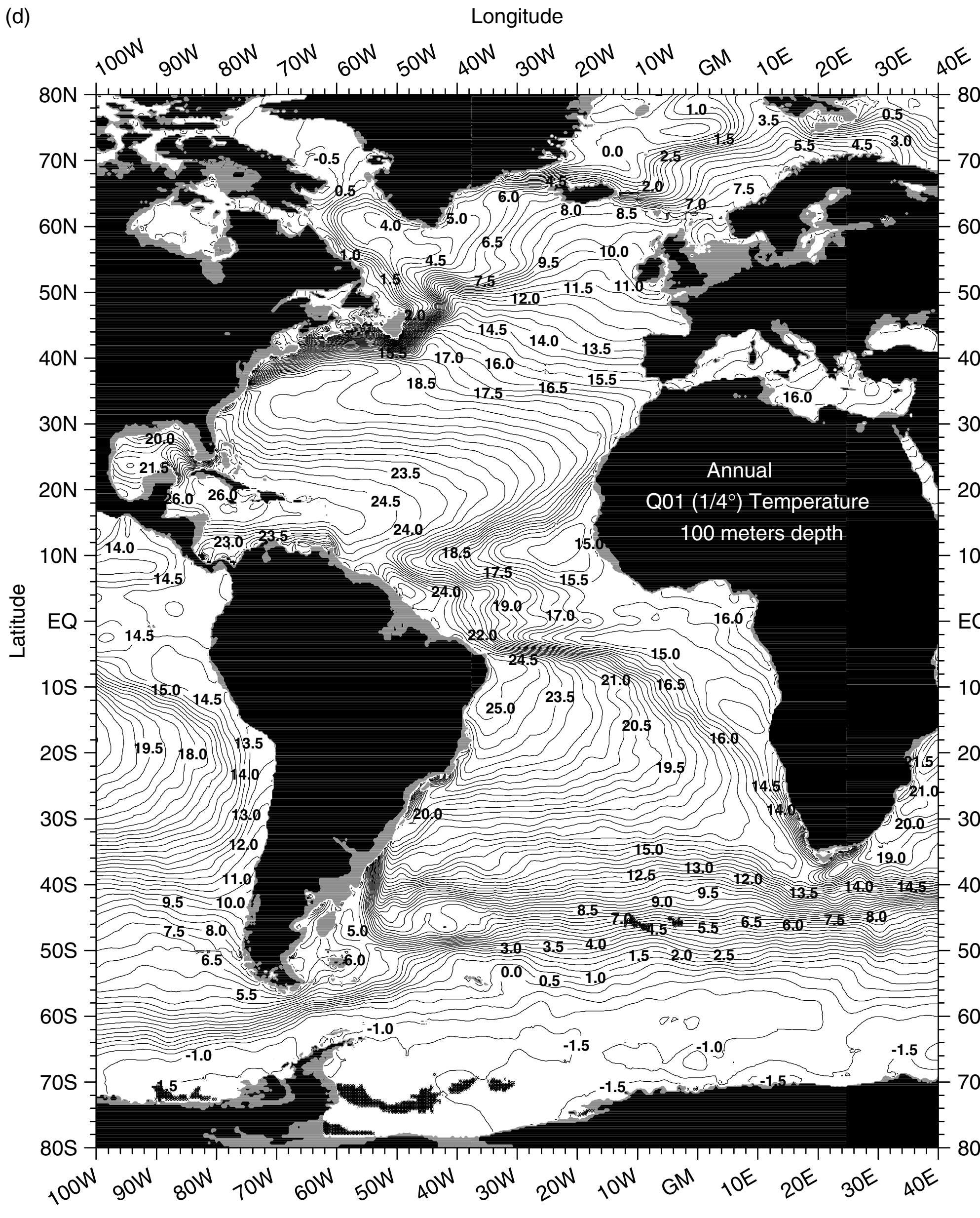

Figure 2. (*Continued*)

are quite similar between W01s and Q01, the western tail of the Agulhas Retroflection is preserved in Q01, whereas it is truncated in W01s.

A notable difference between Boyer and Levitus (1997) and Q01 is the representation of areas of relatively high salinity in the southeast Atlantic. These areas, represented by the medium-grey shading in Figure 3(b) (Boyer and Levitus, 1997), may be due to observations of Agulhas rings. These are rings that break off from the Agulhas Retroflection and bring warm, high-salinity waters northwestward in the South Atlantic. Agulhas rings are a common feature of the southeastern Atlantic Ocean (see Richardson *et al*. (2003) for an overview). The relatively high salinity areas in the South Atlantic in Boyer and Levitus (1997) (Figure 3(b)) are absent in Q01 (Figure 3(c)). However, the monthly fields of Q01 (not shown) display areas of similar

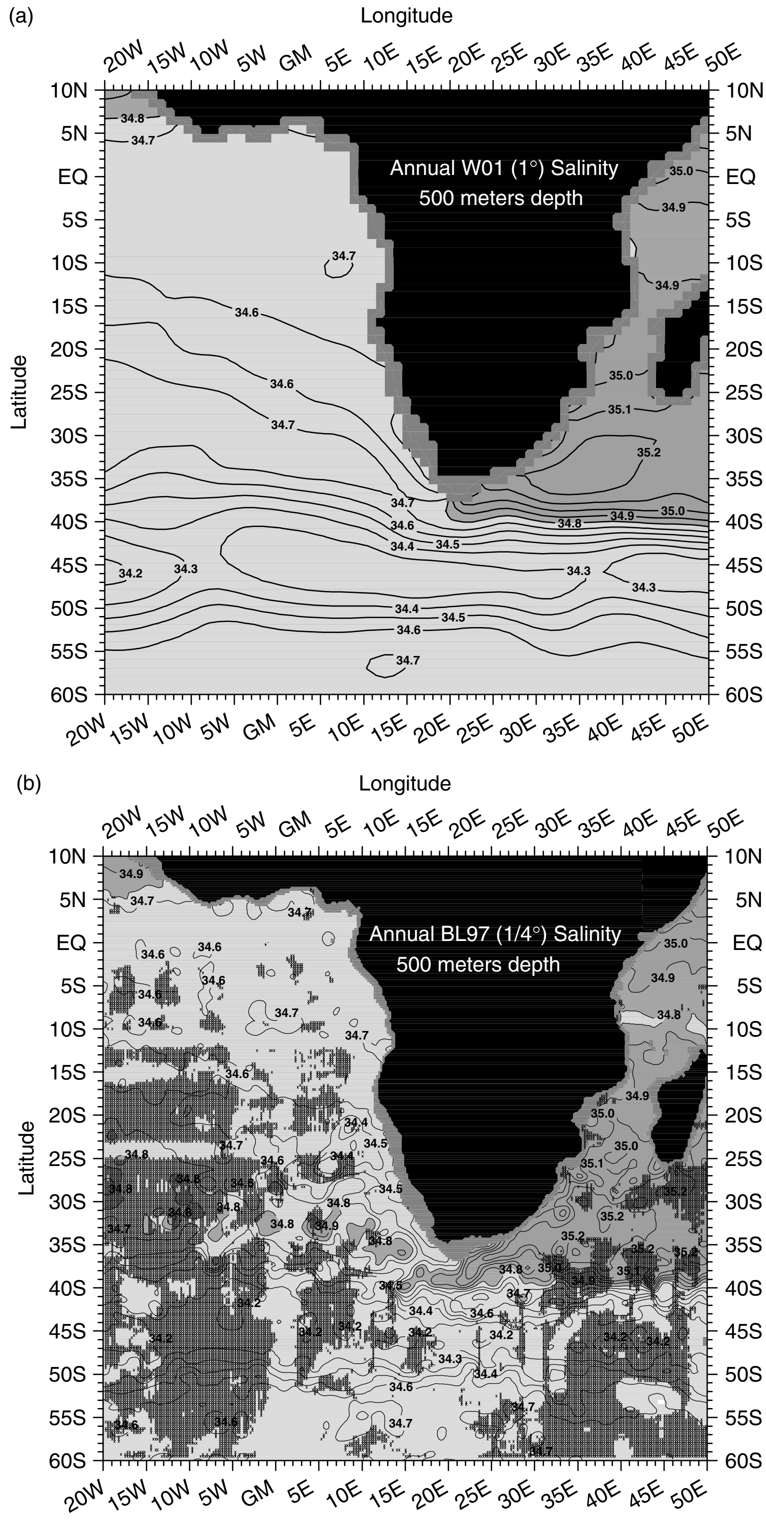

Figure 3. Agulhas Retroflection area salinity at 500 m depth. Salinities greater than 34.8 are shaded medium grey to mark boundary between high-salinity Indian Ocean water and Atlantic Ocean water. Data-sparse grid-boxes are hatched. (a) From 1° annual climatology (W01s); (b) from 0.25° annual climatology (Boyer and Levitus, 1997); (c) from 0.25° annual climatology (Q01)

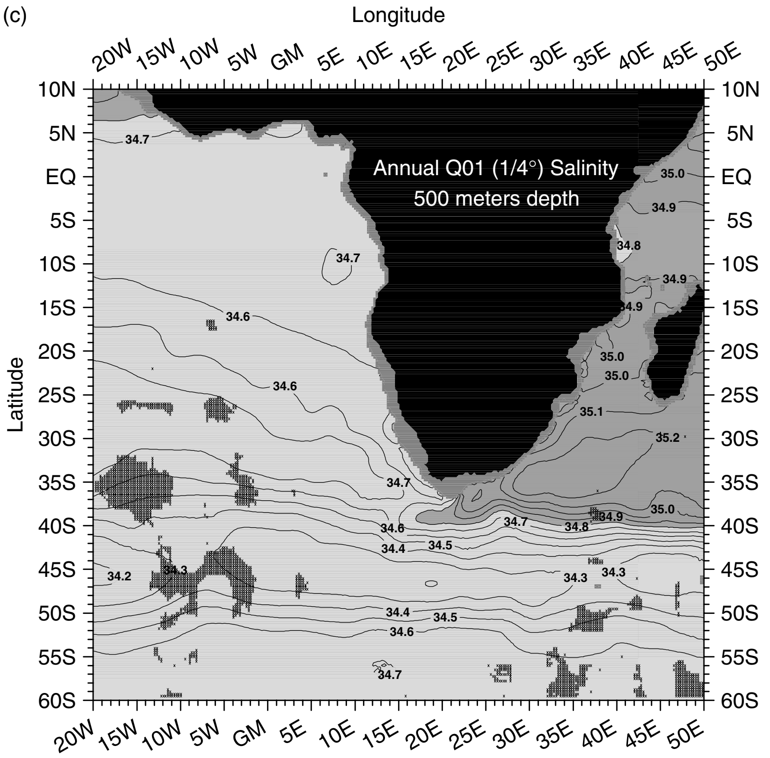

Figure 3. (*Continued*)

relatively high salinity water in different areas of the southeast Atlantic and of different sizes. Thus, it is not the larger radius of influence in Q01, nor the Fourier reconstruction or increased use of median smoothing that removes or reduces the traces of the high salinity from the southeast Atlantic in the annual field for Q01, it is the averaging of the 12 monthly fields used to create the annual field for Q01 that removes the high-salinity traces. This procedure was not carried out in Boyer and Levitus (1997) since the monthly fields were not calculated. In Boyer and Levitus (1997), the point was made that these features are resolvable in a 0.25° climatology. But, since Agulhas rings are transient features that pass through a given southeastern Atlantic grid box, we believe that an all-data annual climatology is better served by representing the mean ocean without the rings, thus representing the average state of the ocean which is then interrupted by the passage of the high-salinity rings. As Levitus (1982) discussed, our analyses are an attempt to represent large-scale permanent or semi-permanent ocean features.

Another notable difference between Boyer and Levitus (1997) data and Q01 is the amount of data-sparse areas, the hatched regions in Figure 3. Much of the area south and west of southern Africa is data sparse in Boyer and Levitus (1997) salinity, whereas very little of the annual Q01 salinity field is data sparse. This is due both to the larger radius of influence applied in Q01 and to additional salinity measurements added for use in Q01.

Figure 4(a) and (b) shows annual mean salinity at a depth of 250 m for the Caribbean for W01s and Q01. Q01 clearly delineates the climatological Loop Current entering and exiting the Gulf of Mexico. W01s (Figure 4(a)) does not have sufficient resolution to resolve the Loop Current. For example, the 36.0 isohaline spans the entire entrance to the gulf in W01s. In contrast, Q01 (Figure 4(b)) reveals the 36.0 isohaline entering seaward of the Yucatan shelf, penetrating some distance into the Gulf of Mexico before looping back and exiting seaward of the Florida shelf. Figure 4(a) and (b) also shows that the gradients associated with the Florida Current are not well resolved at 250 m in W01s, whereas they are better resolved in Q01. Further north, the gradient across the Gulf Stream is sharper in Q01 than in W01s. The gradient across the Gulf

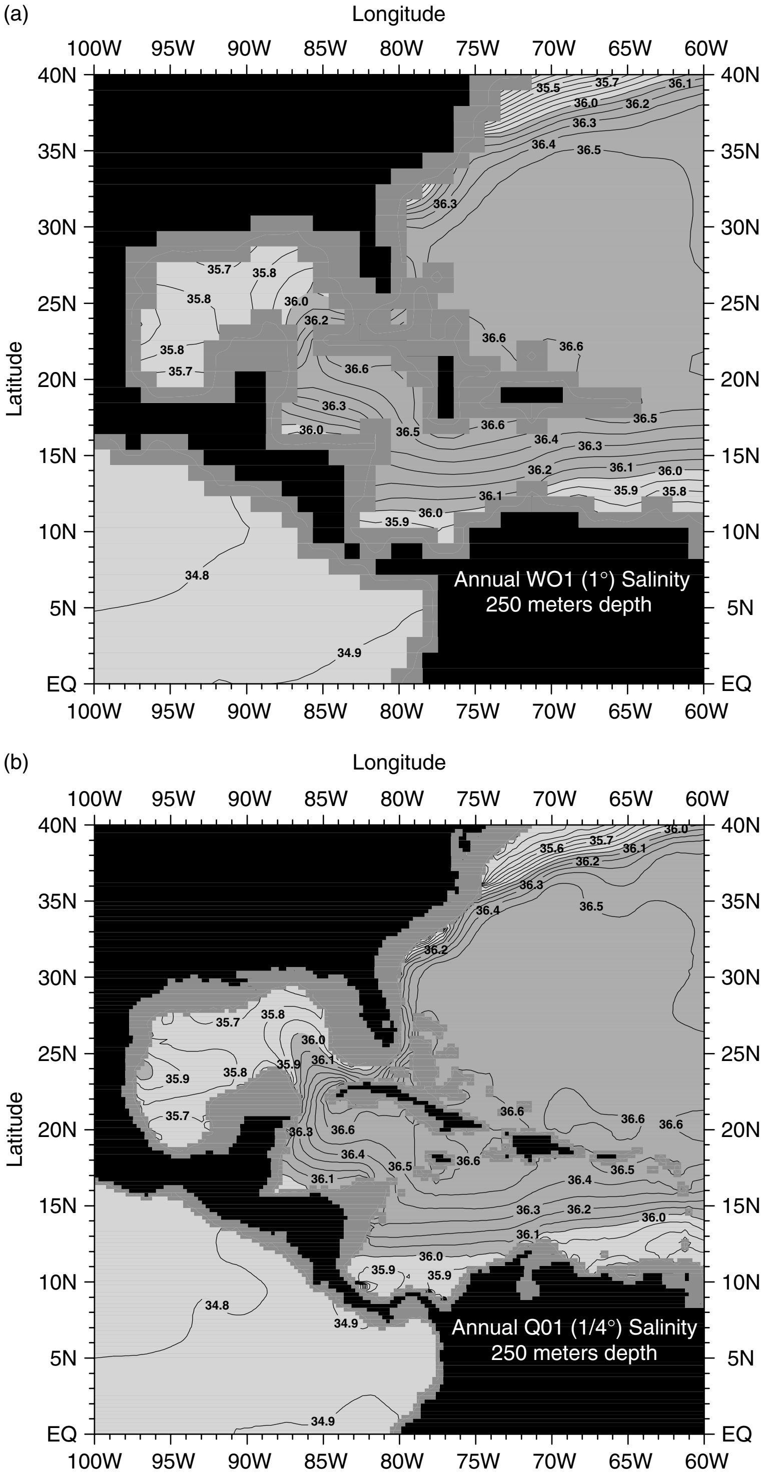

Figure 4. Gulf of Mexico salinity at 250 m depth. Salinities greater than 36.0 are shaded to highlight the Loop Current entering the gulf. Data-sparse grid boxes are hatched. (a) From 1° annual climatology (W01s); (b) from 0.25° annual climatology (Q01); (c) from 0.25° June climatology (Q01); (d) from 0.25° December climatology (Q01)

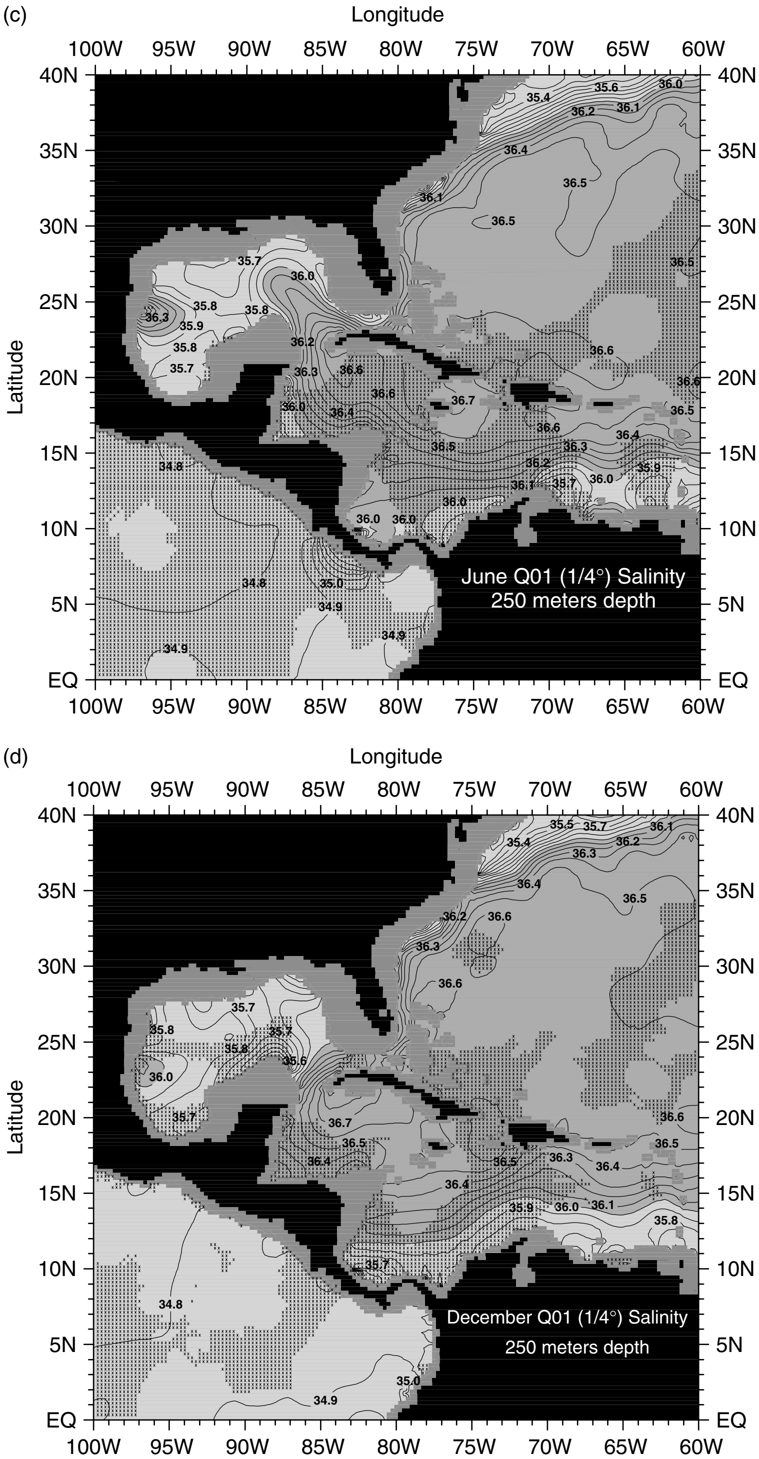

Figure 4. (*Continued*)

Stream in Boyer and Levitus (1997) (not shown) is sharper still than Q01, again illustrating the compromise between preserving gradients and presenting reasonably smooth fields.

In addition to the annual climatological fields of temperature and salinity, Q01 also includes temperature and salinity climatologies for each season and month. Boyer and Levitus (1997) did not include seasonal or monthly fields due to lack of data, especially salinity data. But the salinity profile data on WOD01 represents an 80% increase over the salinity profile data used in Boyer and Levitus (1997). However, this large increase in overall number of salinity profiles is not evenly distributed geographically or temporally. There are still ocean areas, especially in the Southern Hemisphere, that are data sparse for some months or all months in Q01. Even in the western North Atlantic there are some months for which there are large data-sparse areas. Figure 4(c) and (d) shows the 0.25° salinity fields at 250 m depth in the Caribbean for the months of June and December. The Gulf of Mexico is well sampled historically in June, but has data-sparse areas in December, by our definition. The eastern Caribbean is better sampled in December than June, as is the portion of the Pacific Ocean shown. The corresponding 1° climatologies have no data-sparse areas in the region shown in Figure 4, nor do the Q01 annual climatologies. The use of the 1° climatology as the first-guess field also ensures that when data are sparse at the 0.25° resolution, a valid value will still be available for analysis, albeit from a larger radius of influence. So, in areas with more available data, the monthly 0.25° climatology is an improvement over the 1° climatology. Where there is not sufficient data the 0.25° climatology is heavily influenced by the 1° climatology.

4. DISCUSSION

The 0.25° climatological temperature and salinity fields are an improvement over their 1° counterparts. The increased spatial resolution and reduced area over which smoothing is performed resolves small-scale features and prevents oversmoothing in high horizontal gradient areas. Features such as the Loop Current, which are not well represented in the 1° climatologies, are clearly represented in the 0.25° climatology, resulting in a more realistic representation of mean oceanographic characteristics. In addition, the present 0.25° climatology is an improvement over a previous 0.25° climatology (Boyer and Levitus, 1997) because Q01 reduces noise by smoothing in horizontal space (increased radius for median smoothing and radius of influence for objective analysis), in the vertical (stabilizing temperature and salinity fields with respect to density), and in time (Fourier analysis of monthly mean climatologies, averaging monthly mean climatologies for annual, seasonal climatologies).

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This work was made possible by a grant from the NOAA Climate and Global Change Program, which enabled the establishment of a research group at the National Oceanographic Data Center. The purpose of this group is to prepare research-quality oceanographic databases, as well as to compute objective analyses of, and diagnostic studies based on, these databases.

The data on which this atlas is based are in *World Ocean Database 2001* and are distributed on-line and CD-ROM by NODC/WDC. Many data were acquired as a result of the IOC/IODE *Global Oceanographic Data Archaeology and Rescue* (GODAR) project, and the IOC/IODE *World Ocean Database* project (WOD). At NODC/WDC, ‘data archaeology and rescue’ projects are presently supported with funding from the NOAA Environmental Science Data and Information Management (ESDIM) Program and the NOAA climate and Global Change Program. NASA has provided some earlier support for database development. Support for some of the regional IOC/GODAR meetings was provided by the MAST programme of the European Union. The European Community has also provided support for the MEDAR/MEDATLAS project, which has resulted in the inclusion of substantial amounts of ocean profile data from the Mediterranean and Black Seas into *World Ocean Database 2001*.

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