The gsw package

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February 2, 2015

Abstract

The gsw package provides an R implementation of the Gibbs SeaWater toolbox for the calculation of seawater properties. This vignette outlines how to use gsw alone or as part of the oce package.

1 Introduction

In recent years, thermodynamic considerations have led to improved formulae for the calculation of seawater properties (IOC et al., 2010; Millero, 2010), an important component of which is the Gibbs-SeaWater (GSW) toolbox (McDougall and Barker, 2011; Pawlowicz et al., 2012). The gsw package is an R version of GSW, which may be used independently or within the more general oce package (Kelley, 2014).

This vignette sketches how to use gsw. Readers are assumed to be familiar with oceanographic processing, and at least somewhat familiar with GSW. A good resource for learning more about GSW is http://www.teos-10.org, which provides technical manuals for the Matlab version of GSW (http://www.teos-10.org/pubs/gsw/html/gsw_contents.html), along with white papers and links to the growing peer-reviewed literature on the topic.

The gsw framework involves a series of wrappers that connect R with the C version of the Gibbs Seawater library. This yields high processing speed and the minimization of transliteration errors increases reliability[1].

By design, the documentation of gsw functions is spare, amounting mainly to an explanation of function arguments and return values, with most other details being provided through hyperlinks to the GSW reference documentation. The idea is to avoid duplication and to encourage users to consult the technical materials linked to the GSW functions mimicked in gsw. The GSW system is somewhat complex, and analysts owe it to themselves to learn how it works, and also to develop an appreciation for its scientific context by consulting various documents provided on http://www.teos-10.org, including expansive white papers and pointers to the growing peer-reviewed literature, including treatments by Wright et al. (2011), McDougall et al. (2012), Graham and McDougall (2012), and others.

2 Using gsw independent of oce

Suppose a water sample taken at pressure[2] 100 dbar, longitude 188E and latitude 4N, reveals Practical Salinity 35 and in-situ temperature 10 °C (ITS-90). Then the Absolute Salinity may be calculated with

```
library(gsw)
SA <- gsw_SA_from_SP(SP=35, p=100, longitude=188, latitude=4)
```

yielding SA =35.1655 [g/kg], which can then be used to calculate Conservative Temperature with

```
CT <- gsw_CT_from_t(SA=SA, t=10, p=100)
```

yielding CT =9.9782 [°C]. Readers familiar with GSW will recognize the function and argument names, and are likely to find the other functions needed for their work among the roughly 60 that gsw provides.

3 Using gsw within oce

Many oce plotting functions have an argument named eos that can be set to the string "unesco" to get the older seawater formulation, or to "gsw" to get the newer one. For example, the section dataset provided by oce holds a sequence of CTD casts in the North Atlantic. Individual casts may be selected by index, so a TS diagram of the station at index 100 (south of Cape Cod in 4000 m of water) can be plotted as follows (yielding the left-hand panel of Figure 1).

[1]The incorporation of GSW check values into the package-building process is an additional measure taken to achieve reliability.
[2]For practical reasons, gsw goes beyond SI to incorporate oceanographic units, such as decibars for pressure.

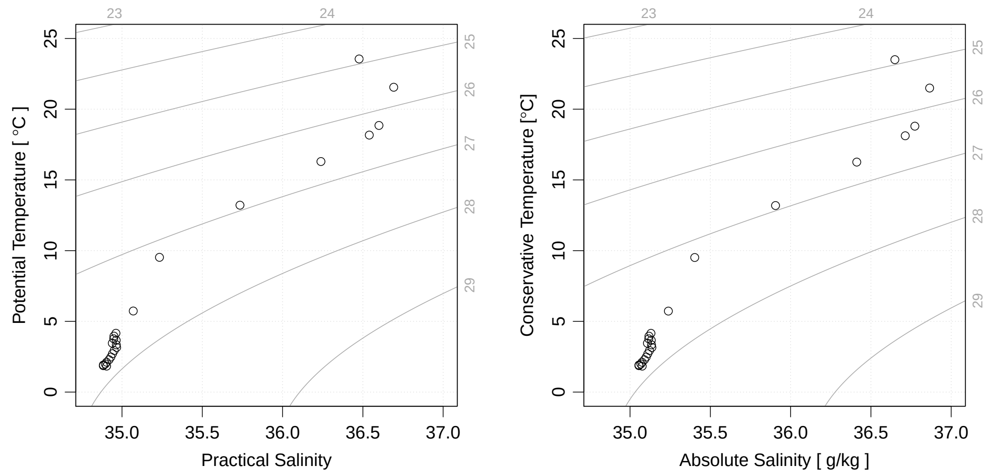

Figure 1: Hydrographic diagram of a CTD cast made in 4 km of water, south of Cape Cod. Left: using the `unesco` formulation; right: using the `gsw` formulation.

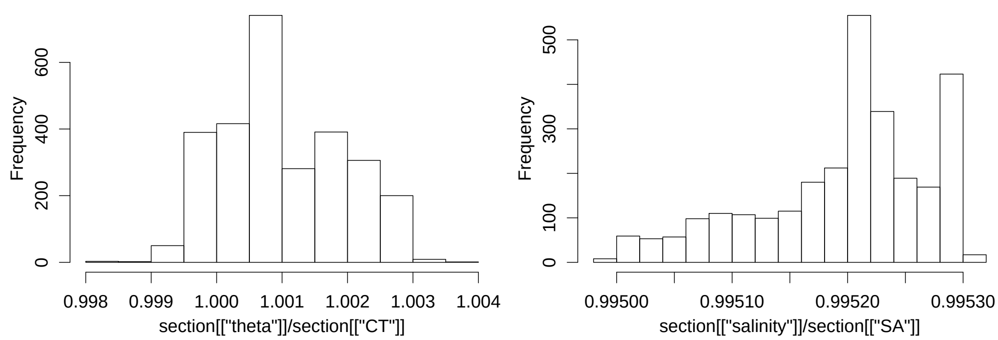

Figure 2: Comparison of `unesco` and `gsw` formulations for a CTD section crossing the Atlantic at 36°N.

```
library(oce)
data(section)
ctd <- section[["station", 100]]
Slim <- c(34.8, 37.0)
Tlim <- c(0, 25)
plotTS(ctd, Slim=Slim, Tlim=Tlim, eos="unesco")
```

where plot limits are used to match axes for a plot using `gsw` (right-hand panel of Figure 1):

```
plotTS(ctd, Slim=Slim, Tlim=Tlim, eos="gsw")
```

Most hydrography-related functions of `oce` provide this `eos` argument for selecting the seawater formulation. This includes functions for plotting and for calculating. In addition, most of the objects within `oce` have accessors that can return temperature and salinity in either the UNESCO-80 or GSW scheme. For example, the ratio of Conservative Temperature to UNESCO-80-formulated potential temperature θ for all the CTD profiles in `section` is constructed as follows (left panel of Figure 2).

```
hist(section[["theta"]] / section[["CT"]], main="")
```

while the corresponding panel comparing Practical Salinity to Absolute Salinity is constructed with

```
hist(section[["salinity"]] / section[["SA"]], main="")
```

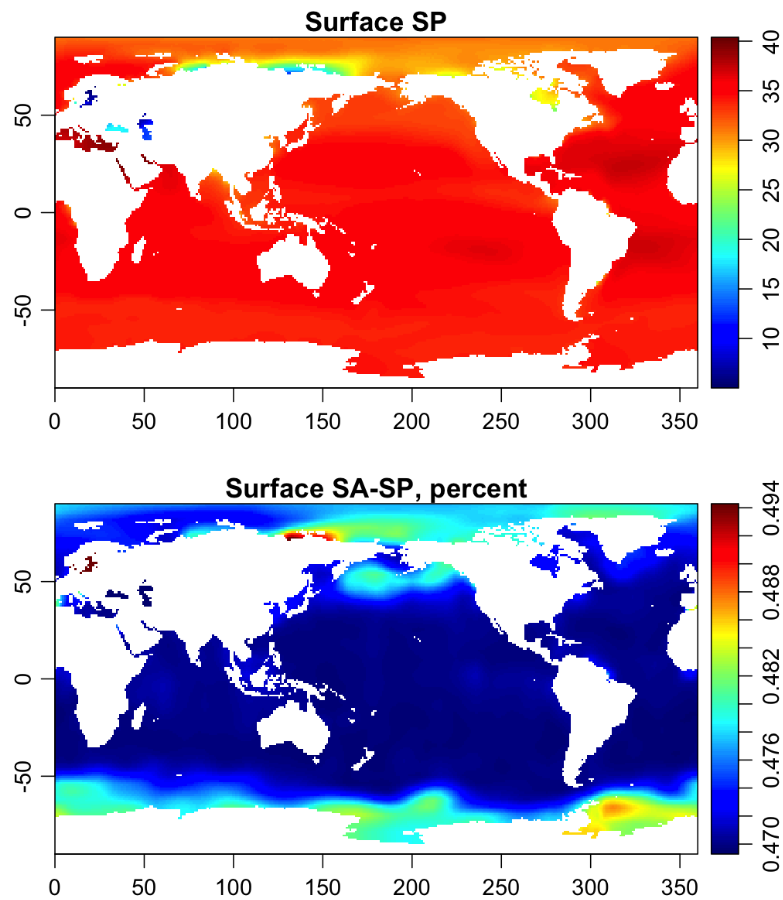

Figure 3: Sea surface Practical Salinity (SP) from the `levitus` dataset and the percent difference between this and Absolute Salinity (SA). In the bottom panel colours are limited to a quantile range, to avoid the scale being set mainly by a contrast between the Baltic and the other salty waters of the planet.

Maps are another way to compare UNESCO-80 and GSW values, e.g. Figure 3 is generated by:

```
data("levitus", package="ocedata")
SSS <- levitus$SSS
dim <- dim(SSS)
ll <- expand.grid(lon=levitus$longitude, lat=levitus$latitude)
SA <- gsw_SA_from_SP(levitus$SSS, 0, ll$lon, ll$lat)
imagep(levitus$longitude, levitus$latitude, levitus$SSS, col=oceColorsJet)
title("Surface SP")
per <- 100 * (1 - levitus$SSS / SA)
imagep(levitus$longitude, levitus$latitude, per, col=oceColorsJet,
       zlim=quantile(per, c(0.001, 0.999), na.rm=TRUE))
title("Surface SA-SP, percent")
```

Note the use of quantile-specified scales for the images, the colour mappings of which would otherwise be controlled by isolated low-saline waters, yielding little to see in the wider expanses of the world ocean; see e.g. McDougall et al. (2012) for a broader context.

References

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