Time Series Database Interface (TSdbi) Guide and Illustrations

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1 Introduction

This vignette illustrates the various *R* (R Core Team, 2014) *TSdbi* packages using time series data from several sources. The main purpose of *TSdbi* is to provide a common *API*, so simplicity of changing the data source is a primary feature. The vignette also illustrates some simple time series manipulation and plotting using packages *tframe* and *tfplot*. While these do not need to be attached for data retrieval, functions in these packages are used in several places in this vignette so they should be attached to run examples in this vignette. This is done with

```
> library("tframe")
> library("tfplot")
```

Package *tframePlus* is also used but will be attached when needed.

To generate this vignette requires most of the *TS** packages, but users will only need one, or a few of these packages. For example, a time series database can be built with several SQL database backends, but typically only one would be used. On the other hand, several packages pull data from various Internet sources, so several of these might be used to accommodate the various specifics of the sources.

If package *TSdata* is installed on your system, it should be possible to view the pdf version of this guide with *vignette("Guide", package="TSdata")*. Otherwise, consider getting the pdf file directly from CRAN at `http://cran.at.r-project.org/web/packages/TSdata/index.html` Many parts of the vignette can be run by loading the appropriate packages, but some examples use data that has been loaded into a local database and it will not be possible to reproduce those examples without the underlying database.

Section 2 of this vignette illustrates the mechanism for connecting to a data source. The connection contains all the source specific information so, once the connection is established, the syntax for retrieving data is similar for different sources. The section illustrates packages that pull data from Internet sources. This currently includes *TSsdmx*, *TSjson*, and *TSmisc*. (Package *TSmisc* is an amalgamation of former packages *TSgetSymbol TShistQuote*, *TSxls*, *TSzip*, and some new connections.) The section starts with a table indicating which packages and connections might be used for various data sources. These packages only get data, they do not support writing data to the database. Finally, the section also illustrates the flexibility to return different representations of time series objects.

Section 3 illustrates the SQL packages *TSPostgreSQL*, *TSMySQL*, *TSSQLite*, and *TSodbc*. These use a very standard SQL table structure and syntax, so it should be possible to use other SQL backends. The package *TSOracle* is available on R-forge at `http://tsdbi.r-forge.r-project.org/` but I currently do not have a server in place to test it properly. (If anyone would be interested in doing this, please contact me, pgilbert.ttv9z@ncf.ca.) These packages get data and also support writing data to the database. See Appendix "B" (separate vignette) and the vignette in package *TSdbi* for more explanation of the underlying database tables, and for bulk loading of data into a database. The section illustrates the packages by writing artificial data to the database.

Section 4 provides additional examples of *TSdbi* functionality and of using and graphing series. Subsection 4.1 illustrates fetching data from the web and loading it into a local database.

Section 5 illustrates package *TScompare* for comparing time series databases, and Section 6 illustrates the use of realtime vintages of data.

Section 7 illustrates some functions for exporting time series data from *R* into .xls and .csv files. While regular *R* users may not be too interested in this, it can be useful for colleagues that are not yet regular users. The section is fairly self contained. (But will give non-users some exposure to *R*, so they may decide they do not actually need to export the data.)

Appendix "A" provides connection details specific to the different database sources, Appendix "B" provides more details about the structure of SQL databases, and Appendix "C" provides some examples of SQL queries that may be useful for database maintenance. Finally, Appendix "D" reproduces the README file for package *TSjson*, to give details regarding installation of Python helper utilities.

Many of the *TS** packages are wrappers of other packages. The purpose is to provide a common API for interfacing with time series databases, and an easy mechanism to specify the type of time series object that should be returned, for example, a *ts* object or a *zoo* (Zeileis and Grothendieck, 2005) object. One consequence of providing a common interface is that special strengths of some of the underlying packages cannot always be used. If you really need some of these features then you will need to go directly to the underlying package. However, if you limit your reliance on these special features then you will be able to move from one data source to another much more easily.

Loading a *TS** package will also attach or load the namespace of required packages *TSdbi*, *DBI* (R Special Interest Group on Databases, 2009), *methods* (R Core Team, 2013), *tframePlus*, *zoo*, and then any underlying package that the specific *TS** package uses.

2 Simple Examples of Time Series Data from the Internet

This section uses packages to pull data from the Internet. The general syntax of a connection is illustrated, and some simple calculations and graphs are done to demonstrate how the data might be used. However, the purpose of the *TS** packages is to provide a common interface, not to do all time series calculations and graphics. Once you have the data, you should be able to use whatever other *R* packages you like for your calculations and graphs.

The generic aspect of the interface API is accomplished by putting the information specific to the underlying source into the "connection". Once the connection is established, other aspects of using data are the same, so one connection can be easily interchanged with another, and so your programs do not need to be changed when the data source is changed. (But, of course, some changes will be needed if the series identifiers of the variables change on the different databases.)

The following table indicates various data sources and the *TS** connections and packages that can be used to extract data from them, *TSsdmx* is a wrapper for package *RJSDMX* (Mattiocco et al., 2014) maintained by Attilio Mattiocco at the Banca d'Italia. It uses SDMX/REST to connect to several important sources for economic data. This API is probably the main future direction, and some of the other interfaces should be considered temporary, pending the institutions getting SDMX/REST 2.1 in place. Package *RJSDMX* has an *addProvider* function which can be used to add SDMX/REST 2.1 compliant servers.

The above URL is for the organization. The SDMX data web URL can be determined with *RJSDMX::sdmxHelp()* using the build command action to give the URL of an sdmx query.

The table is not comprehensive. In particular, Quandl, Bloomberg, Yahoo, Oanda, and some others, provide access to data from a large number of sources, especial market data.

2.1 *SDMX* Data

SDMX is emerging as a widely used standard for time series exchange. It is supported by several large organizations and has evolved over many years. Some of the ad hoc mechanisms in other *TS** packages will be replaced as more organizations implement this standard. It provides capabilites for transmitting large dataset, mixed frequency, and metada. These are well beyond the scope of what is used by the TSdbi API. The *RJSDMX* package provides an interface to SDMX/REST 2.1 compliant databases. Similar to other *TS** packages, the wrapper *TSsdmx* uses only some of the capabilities of the underlying package. Only reading of databases is supported.

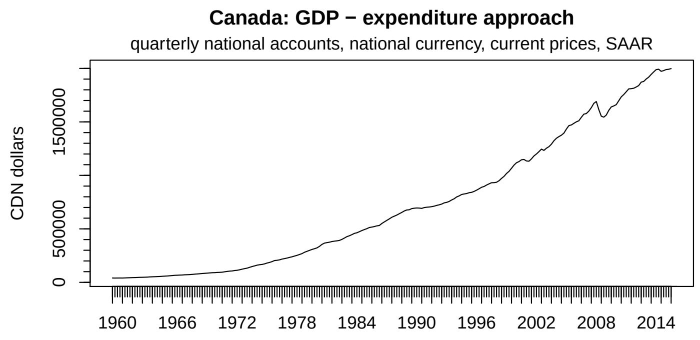
By default *RJSDMX* prints more output than *R* users will typically expect. This output can be supressed by settings in a configuration file, which has been done for this vignette. See Appendix "A" for more details.

```
> library("TSsdmx")
> oecd <- TSconnect("sdmx", dbname="OECD")
> x <- TSget('QNA.CAN.B1_GE.CARSA.Q', oecd)
> tfplot(x, title="Canada: GDP - expenditure approach",
     subtitle="quarterly national accounts, national currency, current prices, SAAR",
     ylab="CDN dollars")
>
```

Table 1: Connections for various data sources.

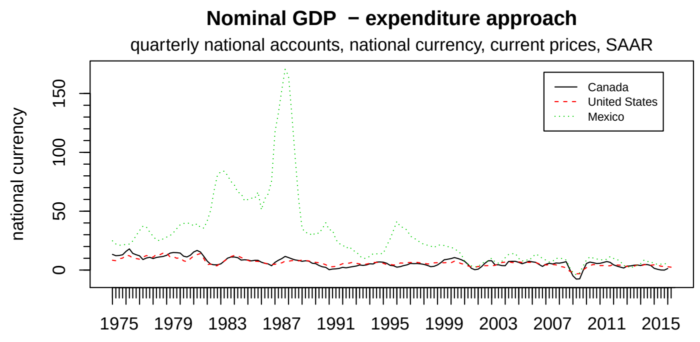
Data source	source URL	Package	Connection
ABS (Australia)	`www.abs.gov.au`	TSsdmx	sdmx
ECB	`www.ecb.org`	TSsdmx	sdmx
EuroStat	`epp.eurostat.ec.europa.eu`	TSsdmx	sdmx
ILO	`www.ilo.org`	TSsdmx	sdmx
IMF	`www.imf.org`	TSsdmx	sdmx
INEGI (Mexico)	`www.inegi.org.mx`	TSsdmx	sdmx
ISTAT[5] (Italy)	`www.istat.it`	TSsdmx	sdmx
NBB (Belgium)	`www.nbb.be`	TSsdmx	sdmx
OECD	`www.oecd.org`	TSsdmx	sdmx
UIS	`www.uis.unesco.org`	TSsdmx	sdmx
UN[2]	`comtrade.un.org`	TSsdmx	sdmx
Unesco	`www.uis.unesco.org`	TSsdmx	sdmx
World Bank[1]	`worldbank.org`	TSsdmx	sdmx
BIS[3]	`www.bis.org`	TSsdmx	sdmx
FRED	`research.stlouisfed.org`	TSmisc	histQuote
FRED	`research.stlouisfed.org`	TSmisc	getSymbol
RBA (Australia)	`www.rba.gov.au`	TSmisc	xls
Statistics Canada	`www.statcan.gc.ca`	TSjson[4,6]	json
Bank of Canada	`www.bank-banque-canada.ca`	TSmisc2[4]	Quandl
Yahoo	`quote.yahoo.com`	TSmisc	getSymbol
Yahoo	`quote.yahoo.com`	TSmisc	histQuote
Oanda	`www.oanda.com`	TSmisc	histQuote
PiTrading	`pitrading.com`	TSmisc	zip
Quandl	`www.quandl.com`	TSmisc2[4]	Quandl
Bloomberg	`www.bloomberg.com`	TSbbg[4]	bbg

[1] beta
[2] planning
[3] requires an account
[4] not on CRAN, on R-forge `tsdbi.r-forge.r-project.org/`
[5] requires free registration at `sdmx.istat.it/registr_ut_sep/`
[6] using python mechanize, unstable website API



SDMX queries are roughly like database queries with the fields separated by dots. They can use ***, |, and + to return muliple series. *TSget* provides the ability to rename series on retrieval when |, and + are used, but not when *** is used.

```
> x <- TSget('QNA.CAN+USA+MEX.B1_GE.CARSA.Q',
          names=c("Canada", "United States", "Mexico"),   oecd)
> tfOnePlot(ytoypc(x), title="Nominal GDP  - expenditure approach",
          subtitle="quarterly national accounts, national currency, current prices, SAAR",
          ylab="national currency", start=c(1975,1),
          legend=seriesNames(x), legend.loc="topright")
```



Several different connections can be defined, and data retreived from them.

```
> eurostat <- TSconnect("sdmx", dbname="EUROSTAT")
> ecb <- TSconnect("sdmx", dbname="ECB")
> abs <- TSconnect("sdmx", dbname="ABS")
> z <- TSget("ei_nama_q.Q.MIO-EUR.NSA.CP.NA-P72.IT", eurostat)
```

TSget allows for specifying start and end dates.

```
> z <- TSget('EXR.Q.USD.EUR.SP00.A',
                  start="2008-Q2", end="2014-Q3", ecb)
> z <- TSget('EXR.Q.USD.EUR.SP00.A',
                  start=c(2008,2), end=c(2014,3), ecb)
```

The first request above uses SDMX syntax for *start* and *end*, which is passed to the query, and only data in the range is returned from the server. The second syntax uses an *R* convention which is difficult to translate into the query, because it is necessary to first determine the frequency of the data. For this query all the data is returned and the truncation is done in *R*. For *sdmx* connections, character string *start* and *end* specifications are assumed to be SDMX and are passed to the underlying *RJSDMX* call and on to the server, otherwise truncation is done in *R* on the returned data.

A connection can be specified to be used as the default, so it does not need to be specified each time:

```
> options(TSconnection=abs)
> z <- TSget("BOP.1.100.10.Q", start=c(1990, 1), end=c(2012, 2))
```

Several different connections will be used in this vignette, and so a default will not be used. To unset the default

```
> options(TSconnection=NULL)
```

By default most *TSget* methods return a class *ts* series when that is possible (annual, quarterly, monthly, or semi-annual data) and *zoo* series otherwise. Thus the class of the series returned above is *ts*, but *zoo* can be specified.

```
> class(z)

[1] "ts"

> z <- TSget("BOP.1.100.10.Q", start=c(1990, 1), end=c(2012, 2),
                   abs, TSrepresentation="zoo")
> class(z)

[1] "zoo"
```

A session default can also be set for this with

```
> options(TSrepresentation="zoo")
```

in which case all results will be return as *zoo* objects unless otherwise specified. The session default is unset with

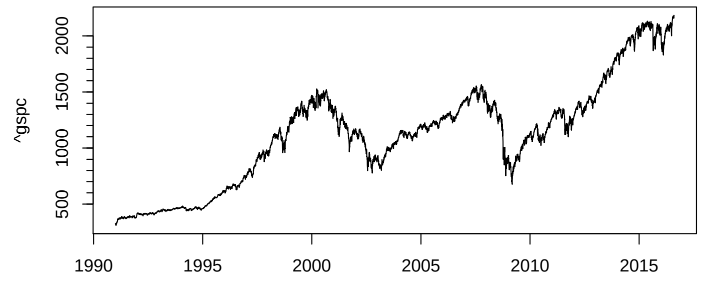
```
> options(TSrepresentation=NULL)
```

Beware that it does not make sense to set *ts* as the default, because it is already the default for all series that can be represented as *ts*, and will not work correctly for other series. Other representations are possible. See the *TSget* help for more details.

2.2 *histQuote* and *getSymbol*

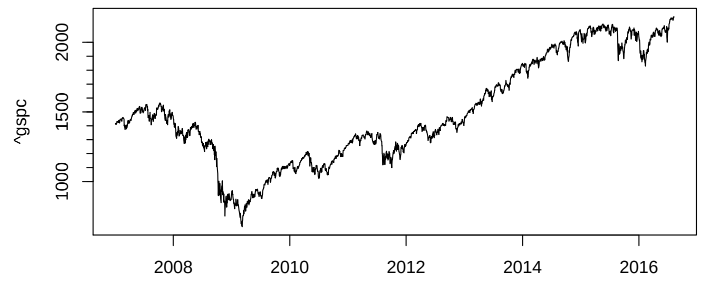
histQuote and *getSymbol* in package *TSmisc* provide mechanisms to retrieve historical quote data from various sources. *histQuote* is a wrapper to *get.hist.quote* in package *tseries* (Trapletti and Hornik, 2012). A connection to Yahoo Finance is established, and data retrieved and plotted by

```
> library("TSmisc")
> yahoo <- TSconnect("histQuote", dbname="yahoo")
> x <- TSget("^gspc", quote = "Close", con=yahoo)
> library("tfplot")
> tfplot(x)
```



Package *getSymbol* is a wrapper to *getSymbols* in package *quantmod* (Ryan, 2011). A connection to Yahoo using this, and retrieving the same data, can be done by

```
> yahoo <- TSconnect("getSymbol", dbname="yahoo")
> x <- TSget("^gspc", quote = "Close", con=yahoo)
> tfplot(x)
```



Notice that the only difference is the name of the driver provided when establishing the connection. After that, the code is the same (and the data from the two connections should be the same, other than the difference in the default start date). This is the coding approach one would typically follow, so that changing the data source is easy. However, sometimes it is interesting to compared the same data from differrent sources, so here is an example where the connections are given different names, so the same data through two different connection methods can be more easily compared:

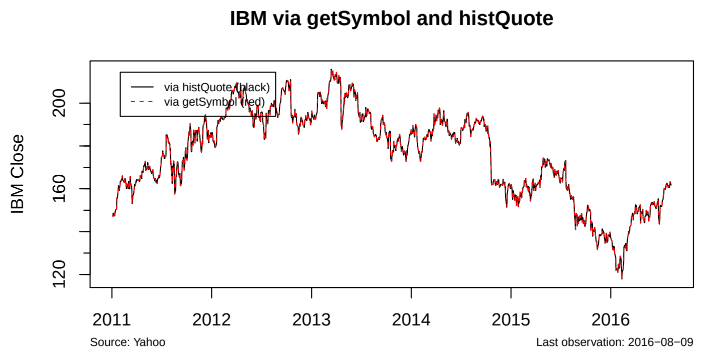
```
> ya1 <- TSconnect("getSymbol", dbname="yahoo")
> ya2 <- TSconnect("histQuote", dbname="yahoo")
> ibmC1 <- TSget("ibm", ya1, quote = "Close", start="2011-01-03")
> ibmC2 <- TSget("ibm", ya2, quote = "Close", start="2011-01-03")
```

In this example the underlying packages both return *zoo* time series objects, but the encoding of the date index vectors are of different classes (*Date* vs *POSIXct*). This is usually not a problem because one would usually work with one package or the other, but it does become a problem when comparing the two objects returned by the different methods. The time representation of *ibmC1* can be changed from *POSIXct* to *Date* by:

```
> tframe(ibmC1) <- as.Date(tframe(ibmC1))
```

The two series can then be plotted:

```
> tfplot(ibmC2, ibmC1,
     ylab="IBM Close",
     title="IBM via getSymbol and histQuote",
     lastObs=TRUE,
     legend=c("via histQuote (black)", "via getSymbol (red)"),
     source="Source: Yahoo")
```



Or the difference can be used to check equality:

```
> max(abs(ibmC2 - ibmC1))
```

```
[1] 0
```

(Note that this difference calculation does not catch a difference in length, which occurs if new data has been release on one connection and not the other. At some point Yahoo was releasing partial data early, and these connection are correcting differently for this. So, at some times of day, the last available data point is not the same on these two connections.)

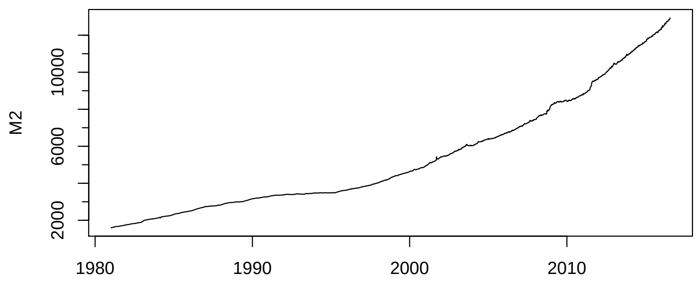
A certain amount of meta data can be returned with the time series object and can be extracted with these utilities:

```
> TSdescription(x)

[1] "^gspc Close  from  yahoo"

> TSdoc(x)

[1] "^gspc Close  from  yahoo retrieved  2016-08-10 11:59:03"

> TSlabel(x)

[1] "^gspc Close"

> TSsource(x)

[1] "yahoo"
```

2.3 *getSymbol* with FRED

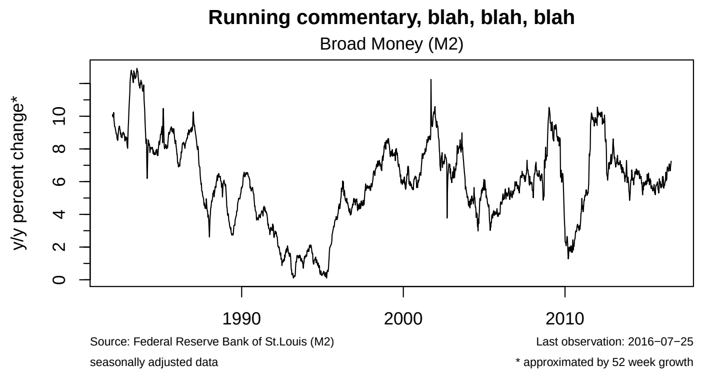
getSymbol can also be used to get data from the Federal Reserve Bank of St.Louis, as will be illustrated here. (Look at `http://research.stlouisfed.org/fred/` to find series identifiers.)

```
> library("TSmisc")
> fred <- TSconnect("getSymbol", dbname="FRED")
> tfplot(TSget("M2", fred))
```



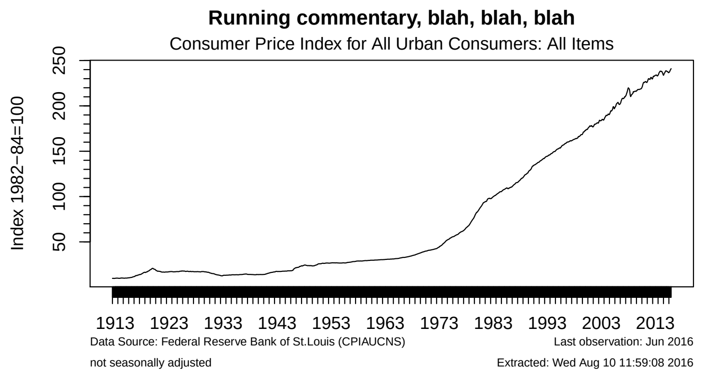
Additional information can be specified in *tfplot* and *tfOnePlot*:

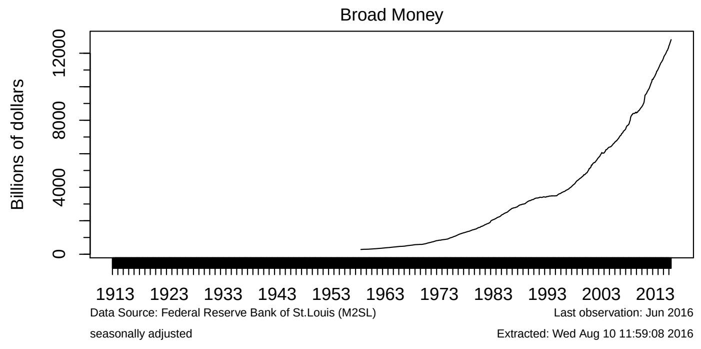
```
> tfOnePlot(percentChange(TSget("M2", fred), lag=52),
      title = "Running commentary, blah, blah, blah",
      subtitle="Broad Money (M2)",
      ylab= "y/y percent change*",
      source="Source: Federal Reserve Bank of St.Louis (M2)",
      footnoteLeft = "seasonally adjusted data",
      footnoteRight = "* approximated by 52 week growth",
      lastObs = TRUE )
```



It is also possible to return multiple series, but they should all be of the same frequency. (The FRED series called M2 is a weekly series).

```
> x <- TSget(c("CPIAUCNS","M2SL"), fred)
> tfplot(x,
      title = "Running commentary, blah, blah, blah",
      subtitle=c("Consumer Price Index for All Urban Consumers: All Items",
                 "Broad Money"),
      ylab= c("Index 1982-84=100", "Billions of dollars"),
      source= c("Data Source: Federal Reserve Bank of St.Louis (CPIAUCNS)",
                "Data Source: Federal Reserve Bank of St.Louis (M2SL)"),
      footnoteLeft  = c("not seasonally adjusted",  "seasonally adjusted"),
      footnoteRight = paste("Extracted:", date()),
      lastObs = TRUE )
```





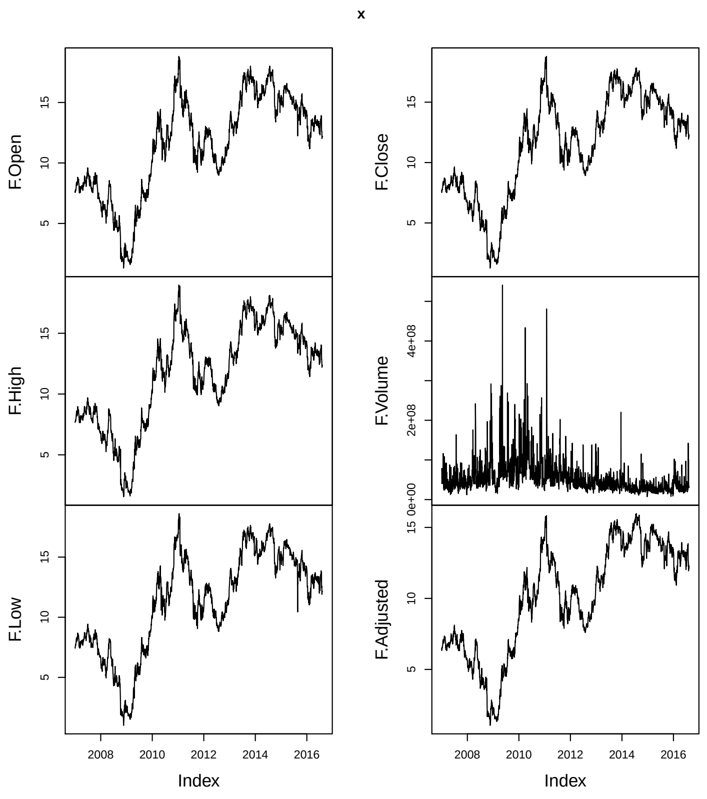
```
> TSdates(c("CPIAUCNS","M2SL"), fred)

     [,1]
[1,] "CPIAUCNS from 1913 1 to 2016 6       12"
[2,] "M2SL from 1959 1 to 2016 6       12"
```

It is possible to specify the type of object to return:

```
> x <- TSget(c("CPIAUCNS","M2SL"), fred, TSrepresentation="zoo")
> class(x)
```

The following connects to yahoo and loads the ticker symbol for Ford. This is a multivariate time series with open, close, etc.

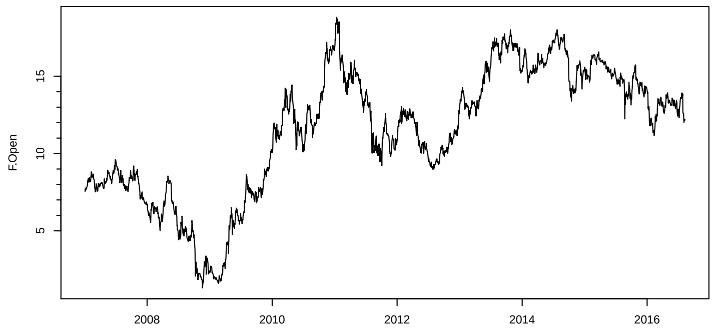
```
> yahoo <- TSconnect("getSymbol", dbname="yahoo")
> x <- TSget("F", con=yahoo)
> plot(x)
```

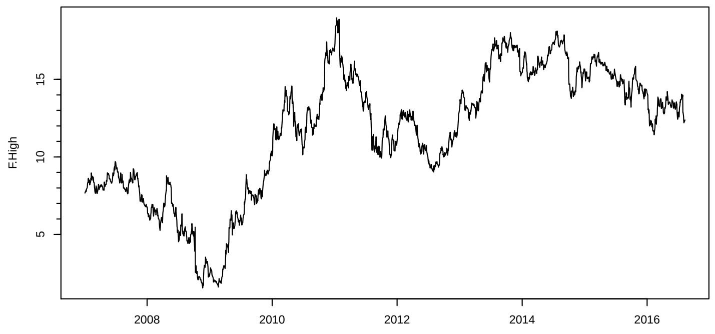


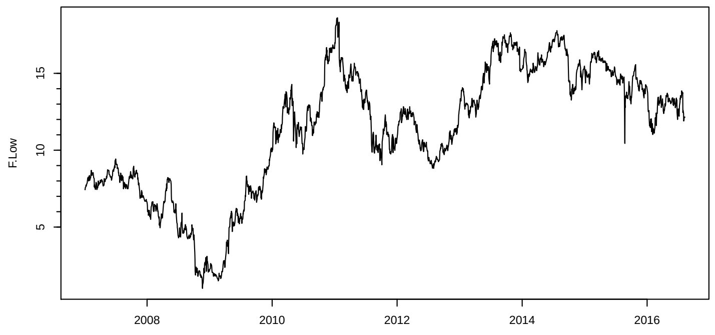
Most of the plots in this vignette are done with the utilities in the *tfplot* package, but the usual *plot* function, used above, produces slightly different results that may be preferable in some situations. Also, for some time series objects, the plot method has been much improved from the default, so if you are using these objects you may find that *plot* provides attractive features.

In the case of the ticker data above, *tfplot* displays graphs in verticle panels. However, six panels do not nicely fit on a printed page. The first three are displayed with:

```
> tfplot(x,series=1:3)
```



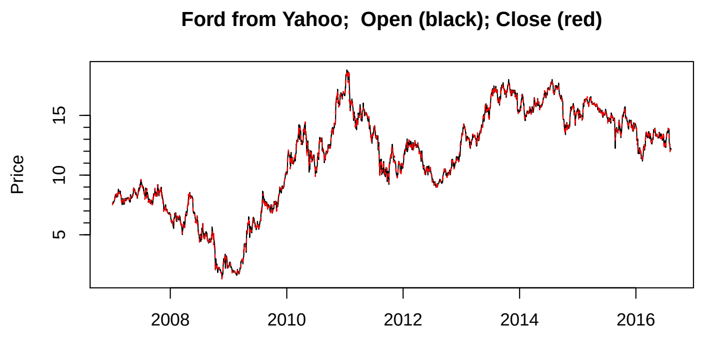




It is possible to specify the number of graphs on an ouput screen with *graphs.per.page*, for example, *tfplot(x, graphs.per.page=3)*. Set *par(ask=TRUE)* if you want to stop and prompt for <Return> between pages in the graphics output.

The *quote* argument to *TSget* can be used to specify that only a subset of the market data should be returned:

```
> tfOnePlot(TSget("F", con=yahoo, quote=c("Open", "Close")),
      title="Ford from Yahoo;  Open (black); Close (red)",
      ylab="Price")
```



2.4 *TSjson* with Statistics Canada

Package *TSjson* provides a mechanism to extract data from websites and pass it to *R* in JavaScript Object Notation (JSON) using package *rjson* (Couture-Beil, 2013). Package *RJSONIO* (Lang, 2012) has previously been used to bring the data into *R* but is not the current method. *TSjson* uses *Python* code to mechanize clicking though web pages to get a downloadable file. This really should be considered a temporary solution, until the data provider implements a true API. The current version of *TSjson* provides a connection to Statistics Canada's `http://www.statcan.gc.ca` Cansim database. (You should look at the Statistics Canada site to find series identifiers.)

The connection can be established in two different ways. The simplest requires a system with *Python* installed, and *Python* modules *sys*, *json*, *mechanize*, *re*, *csv* and *urllib2*. This requires Python 2 as not all modules are available for Python 3. Additional details are provided in a README file distributed with the *TSjson* package and also copied in an appendix here.

Checking that an adequate Python and modules are available on the system can be done with

```
> require('findpython')
> cmdExists <- can_find_python_cmd(
     minimum_version = '2.6',
     maximum_version = '2.9',
     required_modules = c('sys', 're', 'urllib2', 'csv', 'mechanize', 'json')
     )
> if (!cmdExists)  stop('adequate python was not found. ')
```

An adequate python would normally have been needed to install package *TSjson* but system changes after the installation could break it.

Installing Python may be difficult in environments where users cannot easily install software, but a second method using a proxy server can be used. The proxy server needs *Python* and the modules, as well as server software (e.g. *Web2Py*), but the client machine requires nothing special other than *R* and *TSjson*. The proxy server can be anywhere on the Internet.

The following examples use the first method. More details on establishing connections with the second method are provided in the appendix section (separate vignette). First, establish a connection

Although the package *TSjson* usually works, it is not really stable because the web interface is not a proper API and can change from time to time. For this reason, *TSjson* is not on CRAN but available on R-forge at `tsdbi.r-forge.r-project.org/`. The following examples are not being evaluated because failures prevent reliable automatic generation of the vignette.

```
> require("TSjson")
> cansim <- TSconnect("json", dbname="cansim")
```

Now data can be retrieved and a plot generated by

```
> x <- TSget("v498086", cansim)
> tfplot(x)
```

Meta data can also be retrieved:

```
> TSdescription("v498086", cansim)
> TSdoc("v498086", cansim)
> TSlabel("v498086", cansim)
> TSsource("v498086", cansim)
```

A transformation of the data can be done, more detail added to the graph, and a start date specified:

```
> tfplot(ytoypc(x), start=c(1975,1),
     ylab="Year-to-Year Growth Rate",
     title="Canadian GDP",
     source=paste("Statistics Canada ", seriesNames(x)),
     lastObs=TRUE)
```

The default settings of *tfplot* parameters usually work fairly well for interactive use but multi-series graphs may be squashed as above when pdf is output. The next illustrates one way to achieve more specific control, which will often be necessary for generating pdf documents. The series can be retreived and plotted in one step:

```
> oldpar <- par(omi=c(0.1,0.1,0.1,0.1),mar=c(3.1,4.1,0.6,0.1))
> tfplot(ytoypc(TSget(c("v498086", "v498087"), cansim)))
> par(oldpar)
```

Sometimes it is useful to check availability:

```
> TSdates(c("v498086", "v498087"), cansim)
```

The meta data can also be retrieved with the series, which will generally be faster than retreiving it separately, if it is needed:

```
> resMorg <- TSget("V122746", cansim, TSdescription=TRUE,
                    TSdoc=TRUE, TSlabel=TRUE)
> TSdescription(resMorg)
> TSdoc(resMorg)
> TSlabel(resMorg)
> TSseriesIDs(resMorg)
> TSsource(resMorg)
> seriesNames(resMorg) <- "Residential Mortgage Credit (SA)"
> tfplot(ytoypc(resMorg), annualizedGrowth(resMorg),
     title=seriesNames(resMorg),
     subtitle="year-to-year (black) and annualize monthly growth (red)",
     ylab="Growth Rate",
     source=paste("Bank of Canada, ", TSsource(x)),
     lastObs=TRUE)
```

2.5 xls

The *xls* interface allows the use of spreadsheets as if they are a database. (This is a poor substitute for a real database, but is sometimes convenient.) *xls* uses *read.xls* in package *gdata* (Warnes et al., 2011) *xls* does not support writing data to the spreadsheet (but to write time series data to a spreadsheet see *TSwriteXLS* in *tframePlus*, discussed in section 7). The spreadsheet can be a remote file, which is retrieved when the connection is established.

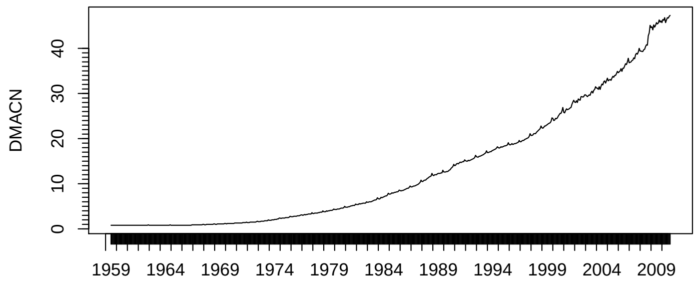
The following retrieves a file from the Reserve Bank of Australia and maps the elements that are used: data, dates, identifiers, and series names.

```
> library("TSmisc")
> rba <- TSconnect("xls", dbname=
        "http://www.rba.gov.au/statistics/tables/xls/d03hist.xls",
      map=list(ids  =list(i=11,     j="B:Q"),
                   data =list(i=12:627, j="B:Q"),
                   dates=list(i=12:627, j="A"),
                   names=list(i=4:7,    j="B:Q"),
                   description = NULL,
                   tsrepresentation = function(data,dates){
                       ts(data,start=c(1959,7), frequency=12)}))
```

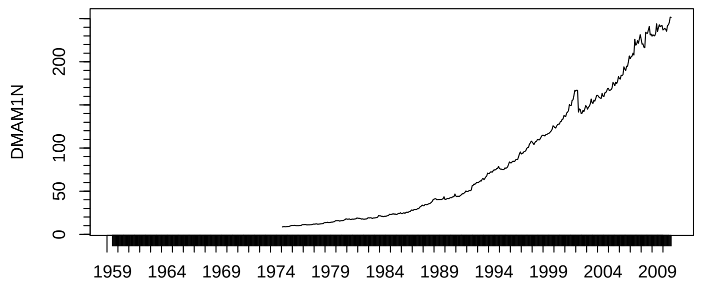
This also illustrates how *tsrepresentation* can be specified as an arbitrary function to set the returned time series object representation. Note also that dates may display in the spreadsheet one way (e.g. 02-Jan-1989), show in the spreadsheet formula box in another way (e.g. 1989-01-02), and import still differently (e.g. 02/Jan/1989). And the format could change when the file is saved, possibly depending on what features are available in the spreadsheet program. The imported format needs to be used when tsrepresentation is specified. If in doubt, look at the connection slot *@dates* (*rba@dates* above).

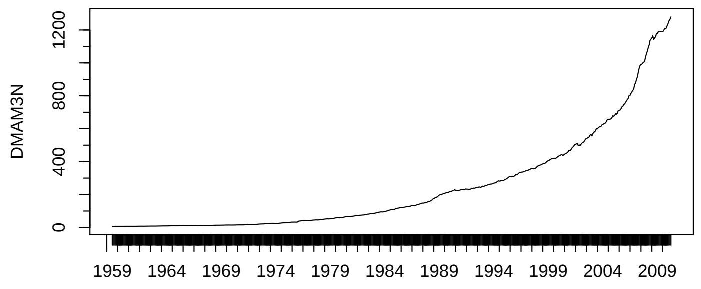
Beware that data is read into *R* when the connection is established, so changes in the spreadsheet will not be visible in *R* until a new connection is established (in contrast to other *TS** packages).

```
> x <- TSget("DMACN", rba)
> require("tfplot")
> tfplot(x)
```



```
> x <- TSget(c("DMAM1N", "DMAM3N"), rba)
> tfplot(x)
> TSdescription(x)

[1] "  from  http://www.rba.gov.au/statistics/tables/xls/d03hist.xls"
[2] "  from  http://www.rba.gov.au/statistics/tables/xls/d03hist.xls"
```

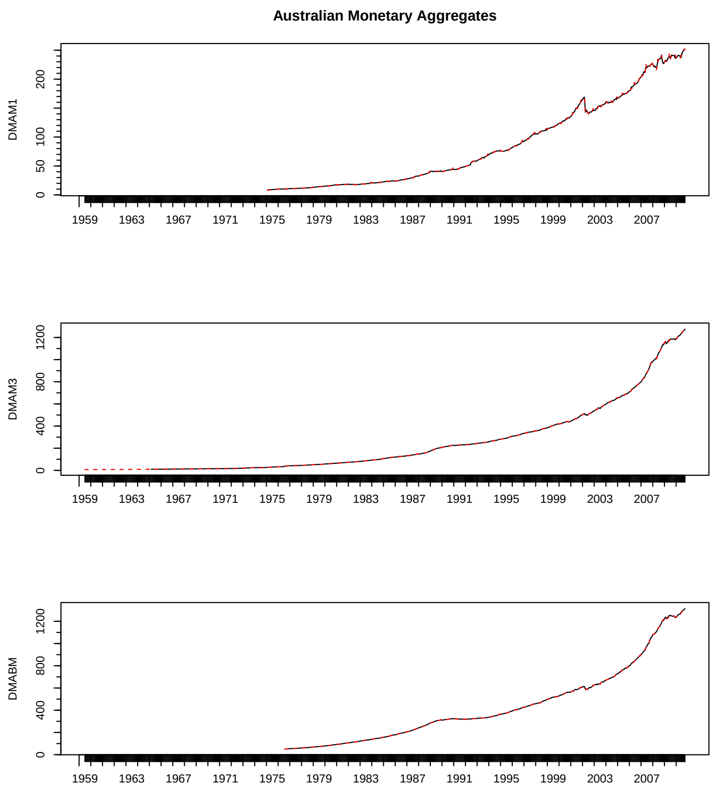




tfplot treats each series in the first argument as a panel to be plotted. It is possible to specify the number of graphs on each page of the output device with the argument *graphs.per.page*. As previously illustrated, it is also possible to specify that a subset of the series should be selected. (Also, as already illustrated above, the function *plot* displays the series somewhat differently than *tfplot*, and possibly differently depending on the objects time series representation.)

tfplot takes additional time series objects as arguments. Series in the first argument are plotted in separate panels. Series in subsequent time series objects will be plotted respectively on the same panels as the first, so the number of series in each object must be the same.

```
> tfplot(TSget(c("DMAM1S", "DMAM3S", "DMABMS"), rba),
          TSget(c("DMAM1N", "DMAM3N", "DMABMN"), rba),
     ylab=c("DMAM1", "DMAM3", "DMABM"),
     title="Australian Monetary Aggregates")
```

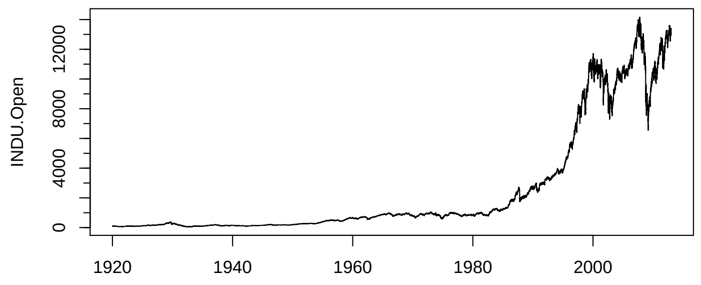


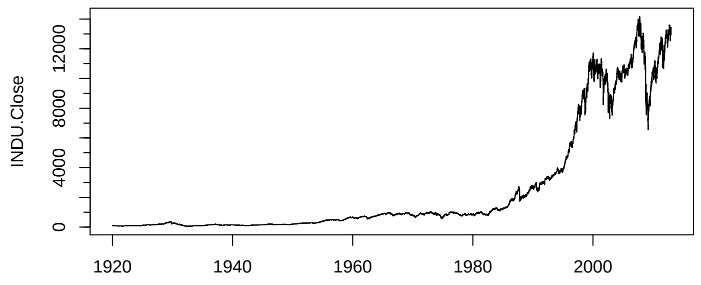
2.6 zip

The *zip* interface allows the use of zipped files that can be read by *read.table* as if each file is a database series (or group of series such as high, low, open, close, for a stock). The *dbname* is a directory or *url*. *zip* does not support writing data to the database.

The following retrieves zipped files from `http://pitrading.com/free_market_data.htm` which provides some end of day data free of charge.

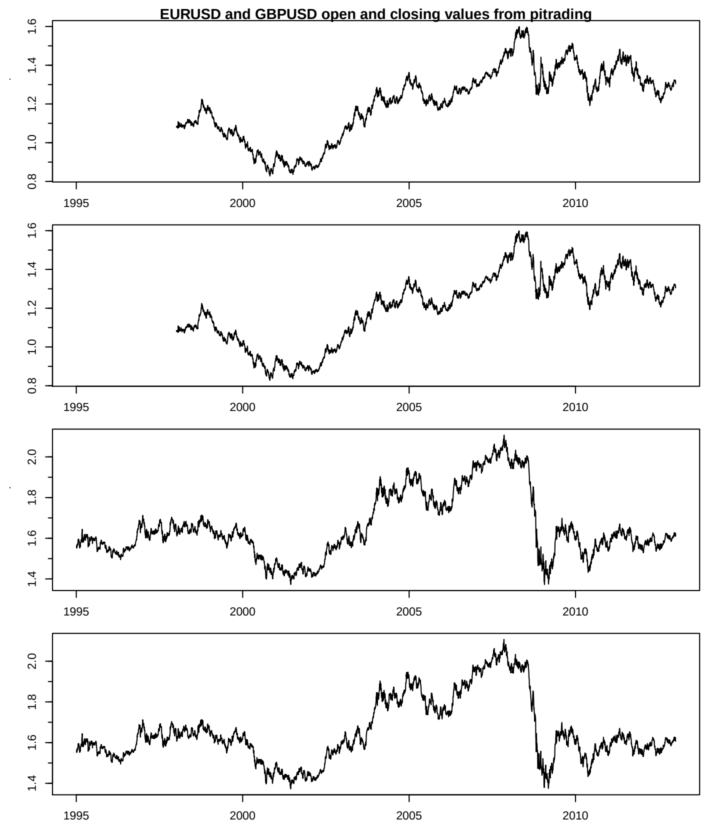
```
> library("TSmisc")
> pitr <- TSconnect("zip", dbname="http://pitrading.com/free_eod_data")
> z <- TSget("INDU", pitr)
> tfplot(z, series=c(1,4))
```





The following illustrates returning an *xts* (Ryan and Ulrich, 2011) time series object.

```
> require("xts")
> z <- TSget(c("EURUSD", "GBPUSD"), pitr, quote=c("Open","Close"),
         TSrepresentation=xts)
> tfplot(z,
         title="EURUSD and GBPUSD open and closing values from pitrading",
         start="1995-01-01",
         par=list(omi=c(0.1,0.3,0.1,0.1),mar=c(2.1,3.1,1.0,0.1)))
```



The default appearance of graphs can be changed (improved) by adjusting graphics device margins *omi* and *mar*. (They are set by the vector in order: bottom, left, top, right.) They can be set directly using *par()* or passed to *tfplot()* as in this example. The default behaviour of *tfplot()* is a compromise that usually works reasonally well for both screen and printed output. It is often useful to adjust these when generating *pdf* files for publication.

3 SQL Time Series Databases

This section gives several simple examples of putting series on and reading them from a database. (If a large number of series are to be loaded into a database, one would typically do this with a batch process using the database program's utilities for loading data.) The examples in this section will use *TSMySQL* but, other than the initial connection, access will be similar for other SQL *TS** packages. The syntax for connecting with other packages, and other options for connecting with *TSMySQL*, are provided in Appendix "A".

The packages *TSPostgreSQL*, *TSMySQL*, *TSSQLite*, and *TSodbc* use underlying packages *RPostgreSQL* (Conway et al., 2012), *RMySQL* (James and DebRoy, 2012), *RSQLite* (James, 2011), and *RODBC* (Ripley and from 1999 to

Oct 2002 Michael Lapsley, 2012). The *TS** packages provide access to an SQL database with an underlying table structure that is set up to store time series data.

The next lines of code do some preliminary setup of the database. This uses the underlying database connection (*dbConnect*) rather than *TSconnect*, because *TSconnect* will not recognize the database until it has been setup. Functon *removeTSdbTables()* is used first to remove any existing tables, which would cause *createTSdbTables()* to fail.

WARNING: running this will overwrite the "test" database on your server.

```
> setup <- RMySQL::dbConnect(RMySQL::MySQL(), dbname="test")
> TSsql::removeTSdbTables(setup, yesIknowWhatIamDoing=TRUE)
> TSsql::createTSdbTables(setup, index=FALSE)
> DBI::dbListTables(setup)
> DBI::dbDisconnect(setup)
```

3.1 Writing to SQL Databases

This subsection illustrates writing some simple artifical data to a database, and reading it back. This part of the vignette is generated using *TSMySQL*, but other backend SQL servers work in a similar way. See Appendix "A" for details of establishing other SQL database connections.

The first thing to do is to establish a *TSdbi* connection to the database:

```
> library("TSMySQL")
> con <- TSconnect("MySQL", dbname="test")
```

TSconnect uses *dbConnect* from the *DBI* package, but checks that the database has expected tables, and checks for additional features. (It cannot be used before the tables are created, as was done above.)

The follow illustrates the use of the *TSdbi* interface, which is common to all extension packages.

This puts a series called *vec* on the database and then reads is back

```
> z <- ts(rnorm(10), start=c(1990,1), frequency=1)
> seriesNames(z) <- "vec"
> if(TSexists("vec", con)) TSdelete("vec", con)
> TSput( z, con)
> z <- TSget("vec", con)
```

Note that the series name(s) and not the *R* variable name (in this case, *vec* not *z*) are used on the database. If the retrieved series is printed it is seen to be a "ts" time series with some extra attributes.

TSput fails if the series already exists on the *con*, so the above example checks and deletes the series if it already exists. *TSreplace* does not fail if the series does not yet exist, so examples below use it instead. *TSput*, *TSdelete*, *TSreplace*, and *TSexists* all return logical values *TRUE* or *FALSE*.

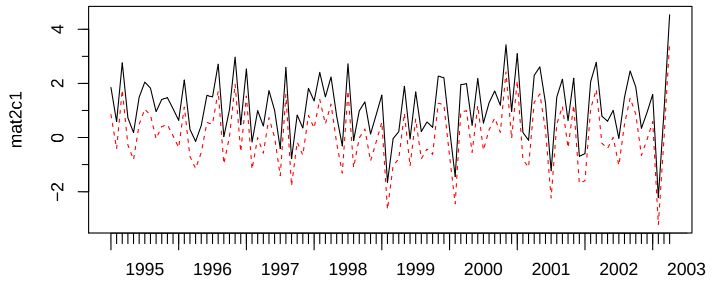
Several plots below show original data and the data retrieved after it is written to the database. In the plot below, one is added to the original data so that both lines are visible.

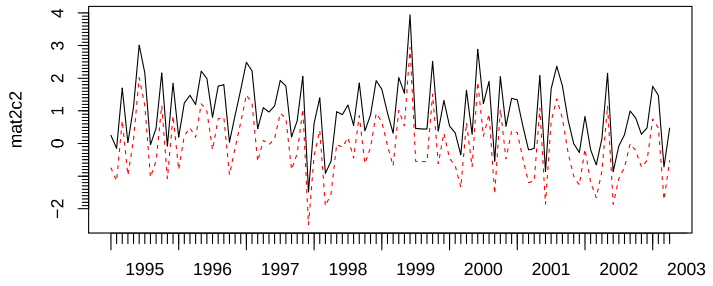
The *R* variable can contain multiple series of the same frequency. They are stored separately on the database.

```
> z <- ts(matrix(rnorm(200),100,2), start=c(1995,1), frequency=12)
>  seriesNames(z) <- c("mat2c1", "mat2c2")
> TSreplace(z, con)
```

```
[1] TRUE
```

```
> tfplot(z+1, TSget(c("mat2c1","mat2c2"), con),
             lty=c("solid", "dashed"), col=c("black", "red"))
```





The following extract information about the series from the database, although not much information has been added for these examples.

```
> TSmeta("mat2c1", con)
```

```
serIDs:  mat2c1
 from dbname  test using  TSMySQLConnection
```

```
> TSmeta("vec", con)

serIDs:  vec
 from dbname  test using  TSMySQLConnection

> TSdates("vec", con)

     [,1]
[1,] "vec from 1990 1 to 1999 1 A       "

> TSdescription("vec", con)

[1] NA

> TSdoc("vec", con)

[1] NA

> TSlabel("vec", con)

[1] NA
```

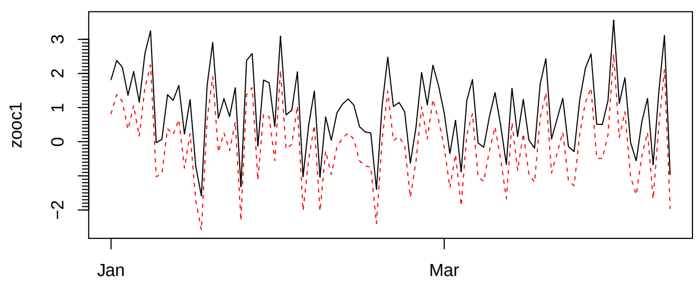
Data documentation can be in three forms. A description specified by *TSdescription*, longer documentation specified by *TSdoc*, or a short label, typically useful on a graph, specified by *TSlabel*. These can be added to the time series object, in which case they will be written to the database when *TSput* or *TSreplace* is used to put the series on the database. Alternatively, they can be specified as arguments to *TSput* or *TSreplace*. The description or documentation will be retrieved as part of the series object with *TSget* only if this is specified with the logical arguments *TSdescription* and *TSdoc*. They can also be retrieved directly from the database with the functions *TSdescription* and *TSdoc*.

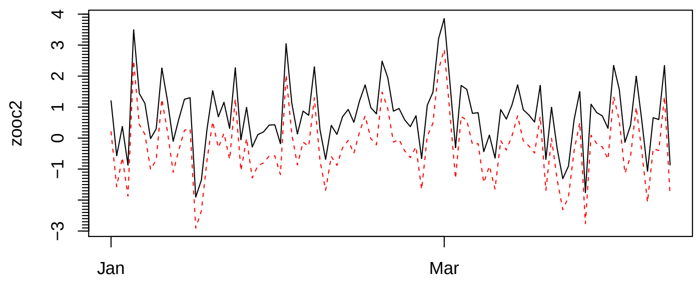
```
> z <- ts(matrix(rnorm(10),10,1), start=c(1990,1), frequency=1)
> TSreplace(z, serIDs="Series1", con)

[1] TRUE

> zz <- TSget("Series1", con)
> TSreplace(z, serIDs="Series1", con,
      TSdescription="short rnorm series",
      TSdoc="Series created as an example in the vignette.")

[1] TRUE

> zz <- TSget("Series1", con, TSdescription=TRUE, TSdoc=TRUE)
> start(zz)

[1] 1990    1
```

```
> end(zz)

[1] 1999    1

> TSdescription(zz)

[1] "short rnorm series"

> TSdoc(zz)

[1] "Series created as an example in the vignette."

> TSdescription("Series1", con)

[1] "short rnorm series"

> TSdoc("Series1", con)

[1] "Series created as an example in the vignette."
```

The following examples use dates and times which are not handled by *ts*, so the *zoo* time representation is used. It is necessary to specify the table where the data should be stored in cases where it is difficult to determine the periodicity of the data. See Appendix "B" for details of the specific tables.

```
> require("zoo")
> z <- zoo(matrix(rnorm(200),100,2), as.Date("1990-01-01") + 0:99)
>  seriesNames(z) <- c("zooc1", "zooc2")
> TSreplace(z, con, Table="D")

[1] TRUE

> tfplot(z+1, TSget(c("zooc1","zooc2"), con),
          lty=c("solid", "dashed"), col=c("black", "red"))
>
```





```
> z <- zoo(matrix(rnorm(200),100,2), as.Date("1990-01-01") + 0:99 * 7)
> seriesNames(z) <- c("zooWc1", "zooWc2")
> TSreplace(z, con, Table="W")

[1] TRUE

> dbDisconnect(con)
> detach(package:TSMySQL)
```

4 More Examples

4.1 Examples Using SQL Databases

This section illustrates fetching data from the web and loading it into the database. This would be a very slow way to load a database, but provides examples of different kinds of time series data. The fetching is done with *histQuote*. Fetching data can fail due to lack of an Internet connection or delays, which will cause the generation of this vignette to fail.

This part of the vignette is generated using *TSPostgreSQL*, but other back-end SQL servers work in a similar way. See Appendix "A" for details of establishing other SQL database connections.

First set up the TS database structure on the database where data will be saved (if it is not already in place)

```
> host        <- Sys.getenv("POSTGRES_HOST")
> setup <-  DBI::dbConnect(RPostgreSQL::PostgreSQL(), dbname="test", host=host)
> TSsql::createTSdbTables(setup)

  tables:
 [1] "meta" "a"    "b"    "d"    "m"    "u"    "q"    "s"    "w"    "i"
[11] "t"

> DBI::dbDisconnect(setup)

[1] TRUE
```

Then establish a TS connection to it:

```
> require("TSPostgreSQL")
> con <-  TSconnect("PostgreSQL", dbname="test", host=host)
```

Now connect to the web server and fetch data:

```
> require("TSmisc")
> yahoo <- TSconnect("histQuote", dbname="yahoo")
> x <- TSget("^gspc", quote = "Close", con=yahoo)
```

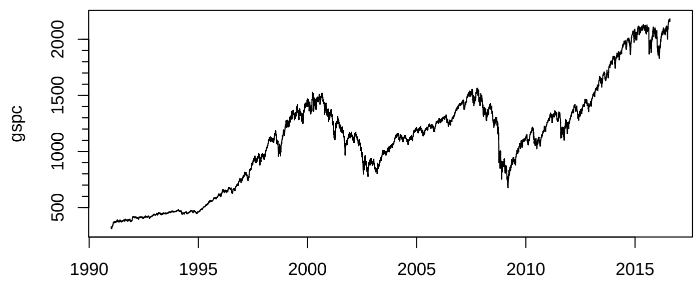
Then write the data to the local server, specifying table B for business day data (using TSreplace in case the series is already there from running this example previously):

```
> TSreplace(x,  serIDs="gspc", Table="B", con=con)

[1] TRUE
```

and check the saved version:

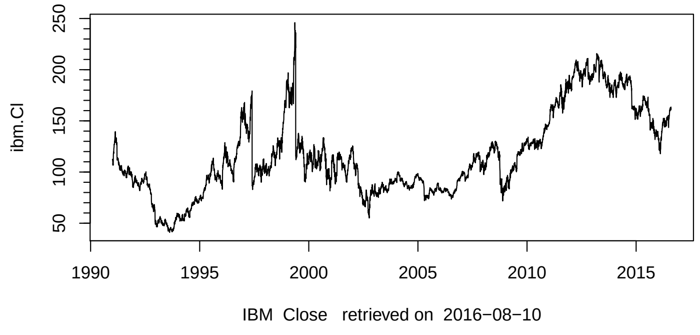
```
> TSrefperiod(TSget(serIDs="gspc", con=con))

[1] "Close"

> TSdescription("gspc", con=con)

[1] "^gspc Close  from  yahoo"

> TSdoc("gspc", con=con)

[1] "^gspc Close  from  yahoo retrieved  2016-08-10 11:59:57"
```

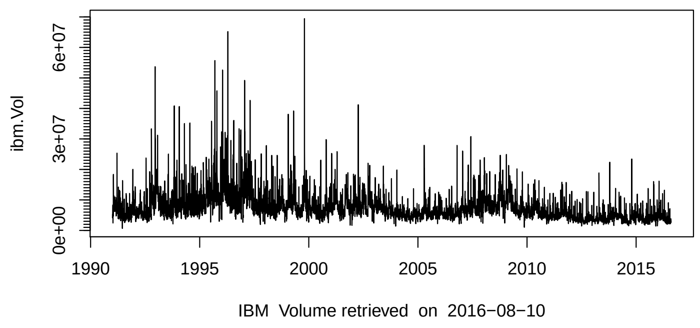
```
> tfplot(TSget(serIDs="gspc", con=con))
```



```
> x <- TSget("ibm", quote = c("Close", "Vol"), con=yahoo)
> TSreplace(x, serIDs=c("ibm.Cl", "ibm.Vol"),  con=con, Table="B",
           TSdescription.=c("IBM Close","IBM  Volume"),
                TSdoc.= paste(c(
                   "IBM  Close   retrieved on ",
                   "IBM  Volume retrieved  on "), Sys.Date()))

[1] TRUE

> z <- TSget(serIDs=c("ibm.Cl", "ibm.Vol"),
          TSdescription=TRUE, TSdoc=TRUE, con=con)
> TSdescription(z)

[1] "IBM Close"   "IBM  Volume"

> TSdoc(z)

[1] "IBM  Close   retrieved on  2016-08-10"
[2] "IBM  Volume retrieved  on  2016-08-10"

> tfplot(z, xlab = TSdoc(z), title = TSdescription(z))
> tfplot(z, title="IBM", start="2007-01-01")
```

IBM Close
IBM Volume



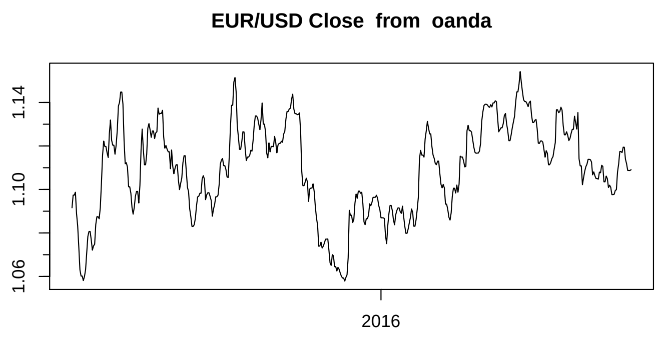


Oanda has maximum of 500 days, so the start date is specified here so as to not exceed that.

```
> Oanda <- TSconnect("histQuote", dbname="oanda")
> x <- TSget("EUR/USD", start=Sys.Date() - 495, con=Oanda)
> TSreplace(x, serIDs="EUR/USD", Table="D", con=con)

[1] TRUE
```

Then check the saved version:

```
> z <- TSget(serIDs="EUR/USD",TSlabel=TRUE,
                  TSdescription=TRUE,  con=con)
> tfplot(z, title = TSdescription(z), ylab=TSlabel(z),
           start="2007-03-01")
```



```
> dbDisconnect(con)
> dbDisconnect(yahoo)
> dbDisconnect(Oanda)
> detach(package:TSPostgreSQL)
```

5 Comparing Time Series Databases

The purpose of package *TScompare* is to compare pairs of series on two database. These series might have the same name, but for generality the main function, *TScompare*, is set up to use name pairs. The pairs to compare are indicated by a matrix of strings with two columns. (It would also be possible to compare pairs on the same database, which might make sense if the names are different.)

The connections are established using other *TSdbi* packages such as *TSMySQL*, *TSPostgreSQL*, etc. It will be necessary to establish two database connections, so it will also be necessary to load the database specific packages. Examples below use *histQuote*, *TSMySQL* and *TSSQLite*.

```
> library("TScompare")
> library("TSmisc")
> library("TSMySQL")
> library("TSSQLite")
```

First setup database tables that are used by TSdbi using a *dbConnect* connection, after which a *TSconnect* connection can be used. This uses the package *TSsql* which does not need to be attached for most purposes, but is needed for the initial setup and for removing *TSdbi* database tables (which destroys the structure *TSconnect* expects). When this is re-done it insure the databases are empty:

```
> setup <- RMySQL::dbConnect(RMySQL::MySQL(), dbname="test")
> TSsql::removeTSdbTables(setup, yesIknowWhatIamDoing=TRUE)
> TSsql::createTSdbTables(setup, index=FALSE)
> DBI::dbListTables(setup)
> DBI::dbDisconnect(setup)
> setup <- RSQLite::dbConnect(RSQLite::SQLite(), dbname="test")
> TSsql::removeTSdbTables(setup, yesIknowWhatIamDoing=TRUE)
> TSsql::createTSdbTables(setup, index=FALSE)
> DBI::dbListTables(setup)
> DBI::dbDisconnect(setup)
```

Now TS connections to the databases are established.

```
> con1 <- TSconnect("MySQL", dbname="test")
> con2 <- TSconnect("SQLite", dbname="test")
```

Next a connection to yahoo is used to get some series and write them to the local test database. *TSreplace* is used because *TSput* will fail if the series already exisits.

```
> yahoo <- TSconnect("histQuote", dbname="yahoo")
> x <- TSget("^gspc", yahoo)
> TSreplace(x,  serIDs="gspc", Table="B", con=con1)

[1] TRUE

> TSreplace(x,  serIDs="gspc", Table="B", con=con2)

[1] TRUE

> x <- TSget("ibm", con=yahoo, quote = c("Close", "Vol"))
> TSreplace(x, serIDs=c("ibmClose", "ibmVol"), Table="B", con=con1)

[1] TRUE

> TSreplace(x, serIDs=c("ibmC",          "ibmV"),   Table="B", con=con2)

[1] TRUE
```

Now to do a comparison:

```
> ids <- AllIds(con1)
> ids

[1] "gspc"     "ibmClose" "ibmVol"
```

If the second database has the same names then ids can be made into a matrix with identical columns.

```
> ids <- cbind(ids, ids)
> eq   <- TScompare(ids, con1, con2, na.rm=FALSE)
> summary(eq)
```

```
3  of  3 are available on con1.
1  of  3 are available on con2.
1  of  1 remaining have the same window.
1  of  1 remaining have the same window and values.
```

```
> eqrm <- TScompare(ids, con1, con2, na.rm=TRUE)
> summary(eqrm)
```

```
3  of  3 are available on con1.
1  of  3 are available on con2.
1  of  1 remaining have the same window.
1  of  1 remaining have the same window and values.
```

Since names are not identical the above indicates discrepancies, which are resolves by indicating the corresponding name pairs:

```
> ids <- matrix(c("gspc","ibmClose", "ibmVol",
                  "gspc","ibmC", "ibmV"),3,2)
> ids
```

```
     [,1]       [,2]
[1,] "gspc"     "gspc"
[2,] "ibmClose" "ibmC"
[3,] "ibmVol"   "ibmV"
```

```
> eq   <- TScompare(ids, con1, con2, na.rm=FALSE)
> summary(eq)
```

```
3  of  3 are available on con1.
3  of  3 are available on con2.
3  of  3 remaining have the same window.
3  of  3 remaining have the same window and values.
```

```
> eqrm <- TScompare(ids, con1, con2, na.rm=TRUE)
> summary(eqrm)
```

```
3  of  3 are available on con1.
3  of  3 are available on con2.
3  of  3 remaining have the same window.
3  of  3 remaining have the same window and values.
```

While it may not be necessary to *detach* packages, the following prevents warnings later about objects being masked:

```
> dbDisconnect(con1)
> dbDisconnect(con2)
> dbDisconnect(yahoo)
> detach(package:TSMySQL)
> detach(package:TSSQLite)
```

6 Vintages of Realtime Data

Examples in the section have been disabled pending availability of a different dataset.

Data vintages, or "realtime data" are snapshots of data that was available at different points in time. The most obvious feature of earlier snapshots is that the series end earlier. However, the reason for retaining vintages is that data is often revised, so, for some observations, earlier vintages have different data. Typically most revisions happen for the most recent periods, but this is often the data of most interest for forcasting and policy decisions. Thus, the revision records are valuable for understanding the implications of differences between early and revised releases of the data. A simple mechanism for accessing vintages of data is available in several *TS** packages. This is illustrated here with an SQL database that has been set up with vintage support.

First establish a connection to th database and get a vector of the available vintages:

```
> require("TSMySQL")
> require("tfplot")
> ets <- TSconnect("MySQL",dbname="etsv")
> v  <- TSvintages(ets)
```

The following checks if a certain variable (Consumer Credit – V122707) is available in the different vintages. (V numbers replaced B numbers circa 2003, so the V numbers do not exist in older vintages. This could be supported by implementing aliases, but that has not been done here.)

```
> ve <- TSexists("V122707", vintage=v, con=ets)
```

```
> ve[224:length(ve)] <- FALSE
```

The vintages can them be retrieved and plotted by

```
> CC <- TSget(serIDs="V122707", con=ets, vintage=v[ve])
> tfOnePlot(ytoypc(CC), start=c(2000,1),
     ylab="Consumer Credit (V122707) y/y Growth",
     title=paste("Vintages", v[ve][1], "to",  v[ve][189]),
     lastObs=TRUE, source="Source: Bank of Canada")
```

With package *TSfame* vintages are supported if the vintages are stored in files with names like "etsmfacansim_20110513.db". Then the vintages can be accessed as follows:

```
> dbs <- paste("ets /path/to/etsmfacansim_", c(
            "20110513.db", "20060526.db", "20110520.db"), sep="")
> names(dbs) <- c("2011-05-13", "2006-05-26", "2011-05-20")
> conetsV <-TSconnect("fame", dbname=dbs, "read", current="2011-05-13")
> z <- TSget("V122646", con=conetsV, vintage=c("2011-05-13", "2006-05-26"))
> dbDisconnect(conetsV)
```

(The above example should work, but beware that I am no longer testing it because I no longer have Fame access.)

The package *googleVis* can be used to produce a plot that is very useful for examining vintage more closely, and finding outliers and other data problems. The names are used in the legend of this next plot, so the series names are specified in the argument to *ytoypc*. (Otherwise they get reset to indicate the year-to-year calculation, which makes the legend messy to read.)

```
> require("googleVis")
> tfVisPlot(ytoypc(CC, names=seriesNames(CC)), start=c(2006,1),
      options=list(title="Vintages of Consumer Credit (V122707) y/y Growth"))
```

This will produce a graph in your web browser. It is not reproduced here. (And beware that it may not be very fast.) Pointing your mouse at the legend of this plot will highlight the corresponding vintage, and pointing at the graph will give information about the source of a data point.

```
> dbDisconnect(ets)
> detach(package:TSMySQL)
```

7 Just Want Data in a xls or csv File

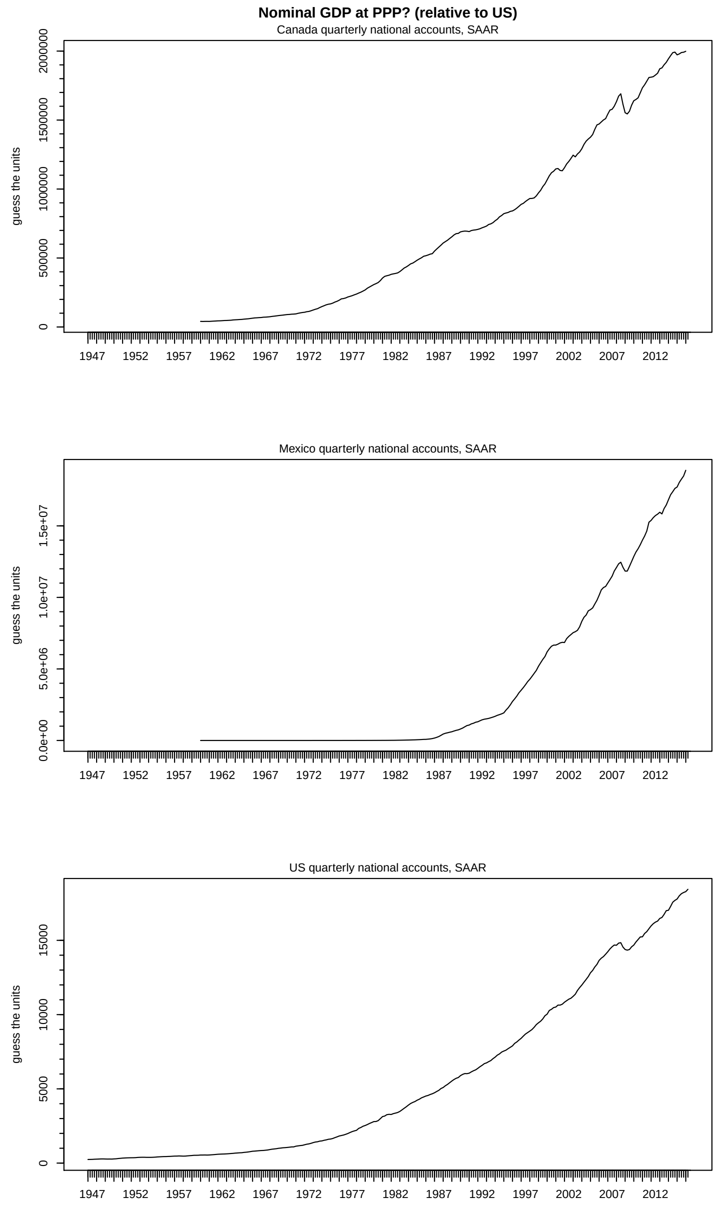
Occasionally one may need to get data into a program other than *R*. Or, perhaps you have a friend that does not want to use *R* but would like easy access to data. This section describes two utilities for putting time series data obtained with *TSdbi* connections into .xls and .csv files. Since it is often straight forward to downlaod an xls or csv file from a web site in the first place, the advantage of this will usually be only in the case where you need to repeatedly get the data. In that case, the process can be automated with these tools.

The starting point will be to get some data. Previous sections illustrate several possibilities. For example purposes here use

```
> library("TSsdmx")
> # RJSDMX::sdmxHelp()  # can be useful for finding series identifiers, etc
>
> oecd <- TSconnect("sdmx", dbname="OECD")
> x <- TSget('QNA.CAN|MEX|USA|.B1_GE.CARSA.Q', oecd)
>
```

While this is optional, it might be useful to look at the data to see if it is really what you expect:

```
> library("tframePlus")
> library("tfplot")
> tfplot(x, title="Nominal GDP at PPP? (relative to US)",
           subtitle=paste(c("Canada","Mexico","US"),"quarterly national accounts, SAAR"),
           ylab=rep("guess the units",3))
```



If the data in one series starts at a different time then z will be filled with NA for missing points. It is possible to trim the NA data from the beginning with

```
> start(x)
```

```
[1] 1947    1
```

```
> x <- trimNA(x, endNAs=FALSE)
> start(x)
```

```
[1] 1960    1
```

By default, *trimNA* will trim all series if any one of them is *NA*, so trimming the end will not be what you want if you are interested in the most recent data. Setting *endNAs=FALSE)* overrides the default.

It is also possible to trim the data to a specified subsample with

```
> x <- tfwindow(x, start=c(1995,1))
```

Now write the data to an .xls file using *TSwriteXLS* which uses *WriteXLS* (Schwartz, 2012) but automatically adds time information:

```
> library("WriteXLS")
> tofile <- tempfile(fileext = ".xls")
> TSwriteXLS(x, FileName=tofile)
> unlink(tofile)
```

In this case a temporary file is written, then removed with *unlink*, so that scratch files do not accumulate from building this vignette, but you would typically use a more meaningful name, and not remove the file. It is also possible to write multiple sheets in the file. For more details on this see the help

```
> ?TSwriteXLS
```

The dates are written in some different formats in the .xls file, since this is often convenient for calculations and graphing in a spreadsheet program. Beware that .xls files have size limitations that you might encounter if you try to put large amounts of data into the file. Consider using .csv files in that case.

To write the data to a .csv file

```
> tofile <- tempfile(fileext = ".csv")
> TSwriteCSV(x, FileName=tofile)
> unlink(tofile)
```

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