Time Series Analysis: Forecasting Average Global Temperatures

Maple includes powerful tools for accessing, analyzing, and visualizing time series data. This application works with global temperature data to demonstrate techniques for analyzing time series data sets using the TimeSeriesAnalysis package, including visualizing trends and modeling future global temperatures.

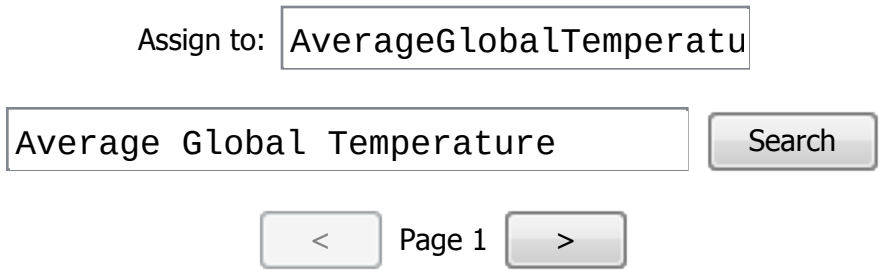
```
> with(DataSets):
  with(TimeSeriesAnalysis):
```

Global Temperature Data

The following example uses a data set containing yearly global temperature measurements from 1901 to 2010. The data is compiled by the Earth Policy Institute from National Aeronautics and Space Administration (NASA) and Goddard Institute for Space Studies (GISS).

The first step is to retrieve the data. You can search for this data using the help search box, or by inserting a search box in the Maple worksheet.

```
> InsertSearchBox(search = "Average Global Temperature", assign = 'AverageGlobalTemperature')
```



1. Average Global Temperature, 1880-2010
2. Global Temperature Anomalies
3. Temperature Perfection Twitter Metrics
4. Timor-Leste: Droughts, floods, extreme temperatures (% of population, average 1990-2009)
5. Belgium: Droughts, floods, extreme temperatures (% of population, average 1990-2009)
6. Guinea: Droughts, floods, extreme temperatures (% of population, average 1990-2009)
7. Netherlands: Droughts, floods, extreme temperatures (% of population, average 1990-2009)
8. Uruguay: Droughts, floods, extreme temperatures (% of population, average 1990-2009)
9. Colombia: Droughts, floods, extreme temperatures (% of population, average 1990-2009)
10. Nicaragua: Droughts, floods, extreme temperatures (% of population, average 1990-2009)

```
Note: The margin of error for these data
is 0.05 °C; as such, it is impossible to
distinguish between the years 2005 and
2010 on a statistical level.
Source: Compiled by Earth Policy
Institute from National Aeronautics and
Space Administration (NASA), Goddard
Institute for Space Studies (GISS),
\"Global Land-Ocean Temperature Index in
```

Start: 1880-12-31 End: 2010-12-31

Frequency: Daily Weekly Monthly Quarterly Annual

Columns: Temperature (Degrees Celsius)

As you can see in the command earlier, this search result is assigned to AverageGlobalTemperature.

> *AverageGlobalTemperature*

$$\begin{bmatrix} \textit{Data set} \\ \textit{Average Global Temperature, 1880-2010} \\ \textit{Quandl EPI/74} \\ \textit{up to 131 rows (annual), 1 column} \\ \textit{1880-12-31 - 2010-12-31} \end{bmatrix} \quad \textbf{(1.1)}$$

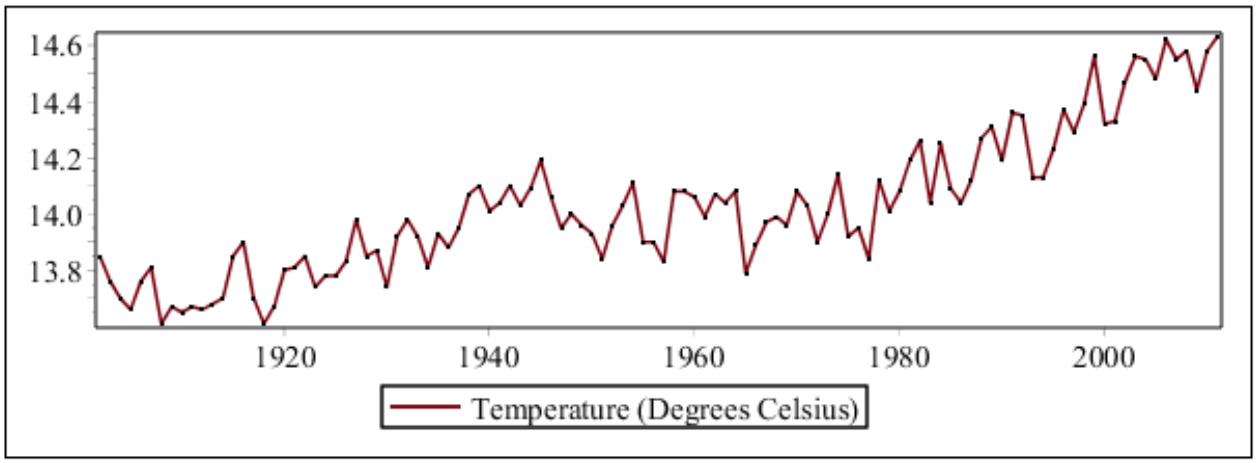
This data set is provided by Quandl, so you can also retrieve this directly using the Quandl code: "EPI/74"

> *AverageGlobalTemperature* := *SetFromDate*(*Reference*("quandl", "EPI/74"), "1901-12-31")

$$AverageGlobalTemperature := \begin{bmatrix} Data\ set \\ Average\ Global\ Temperature,\ 1880\text{-}2010 \\ Quandl\ EPI/74 \\ up\ to\ 110\ rows\ (annual),\ 1\ column \\ 1901\text{-}12\text{-}31\ -\ 2010\text{-}12\text{-}31 \end{bmatrix} \quad (1.2)$$

The data can be plotted using the TimeSeriesPlot command:

> *TimeSeriesPlot*(*AverageGlobalTemperature*)



Visualizing Trend & Modeling Future Global Temperatures

From the previous plot, it can be observed that the time series seems to have an upwards trend. To forecast future temperatures, first find a suitable model to match the actual data. Maple can select a suitable model from a family of 30 related models and adjust it to this time series.

> *model* := *ExponentialSmoothingModel*(*AverageGlobalTemperature*)

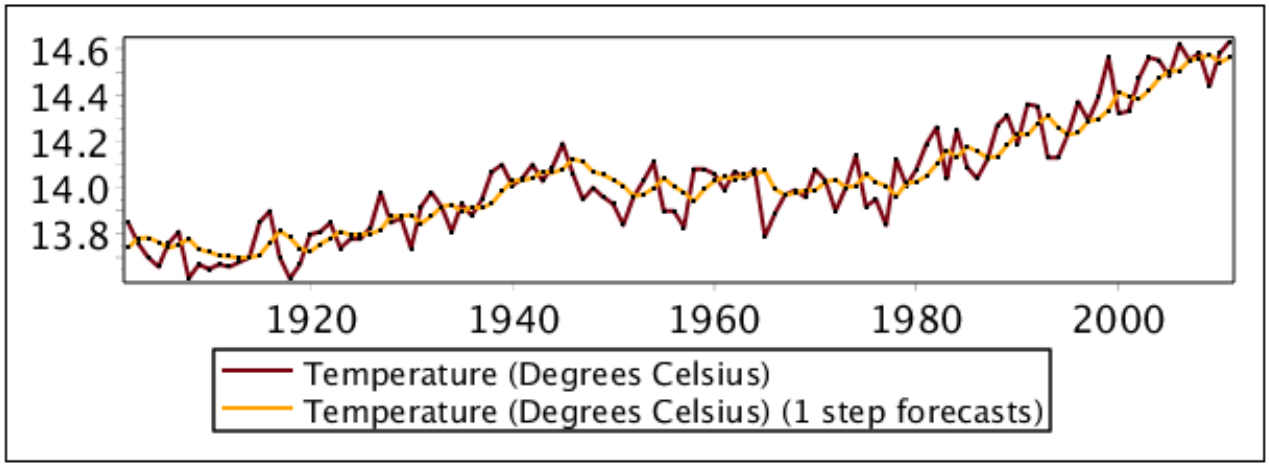
$$model := \langle\ an\ ETS(A,A,N)\ model\ \rangle \quad (2.1)$$

To evaluate the fit of the model, view the OneStepForecast:

> *modelts* := *OneStepForecasts*(*model*, *AverageGlobalTemperature*)

$$modelts := \begin{bmatrix} Time\ series \\ Temperature\ (Degrees\ Celsius)\ (1\ step\ forecasts) \\ 110\ rows\ of\ data: \\ 1901\text{-}12\text{-}31\ -\ 2010\text{-}12\text{-}31 \end{bmatrix} \quad (2.2)$$

> *TimeSeriesPlot*([*modelts*, *color* = "Orange", *thickness* = 2], [*AverageGlobalTemperature*, *color* = "Niagara Burgundy", *thickness* = 2], *font* = ["Helvetica", 14], *legendstyle* = [*font* = ["Helvetica"]])



From this plot, you can see that the forecast model follows the data suitably well. Using the model data, you can predict twenty years of future data using the forecast command and include a 95% confidence interval in order to see if the trend for global temperatures continues to increase based on previous data.

```
> ForecastTemperatures
      := Forecast(ExponentialSmoothingModel(AverageGlobalTemperature),
      AverageGlobalTemperature, 20, output = confidenceintervals(95))
```

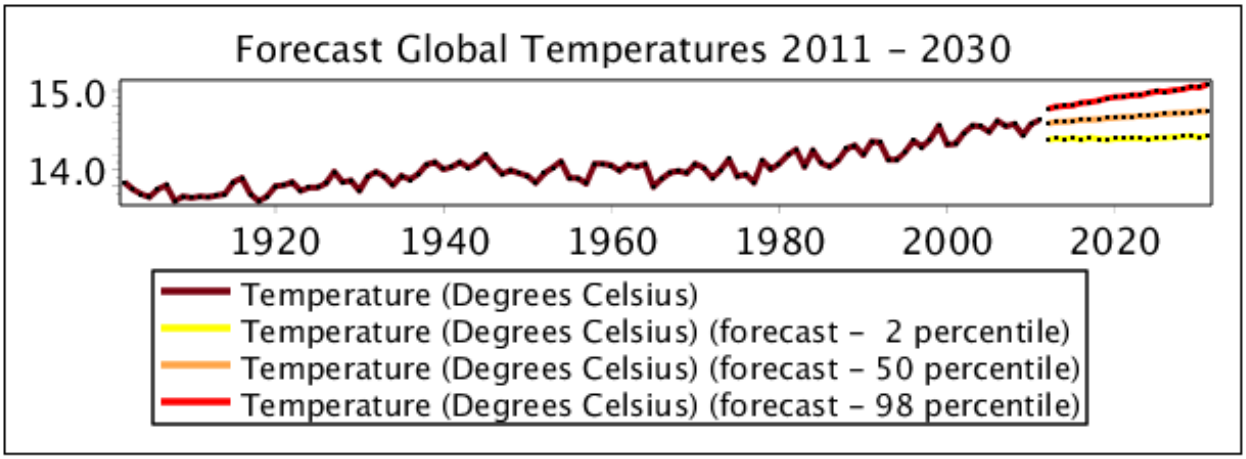
$$\mathit{ForecastTemperatures} := [[\mathit{Time\ series}], \quad \textbf{(2.3)}$$

$$[\mathit{Temperature\ (Degrees\ Celsius)\ (forecast\ -\ \ 2\ percentile)}, \mathit{Temperature\ (Degrees\ Celsius)\ (forecast\ -\ 50\ percentile)}, \mathit{Temperature\ (Degrees\ Celsius)\ (forecast\ -\ 98\ percentile)}],$$

$$[\mathit{20\ rows\ of\ data:}],$$

$$[\mathit{2011\text{-}12\text{-}31\ -\ 2030\text{-}12\text{-}30}]]$$

```
> TimeSeriesPlot( AverageGlobalTemperature, [ForecastTemperatures, color = "Yellow"
      .."Red" ], title = "Forecast Global Temperatures 2011 - 2030", thickness = 3, font
      = ["Helvetica", 14], legendstyle = [font = ["Helvetica"]])
```



From this plot, you can observe that based on the past 100 years of data, the trend

indicates that global temperatures will increase.

```
> max(GetData(ForecastTemperatures[2])) - min(GetData(ForecastTemperatures[2]))
```

$$0.15392519 \quad (2.4)$$

Based on the forecast model, you can expect the global temperature to go up 0.15°C over the next twenty years.

Notes

```
> DocumentTools:-Tabulate(["Notes", GetDescription(AverageGlobalTemperature)], weights
      = [10, 90], fillcolor = "WhiteSmoke")
```

Notes	Note: The margin of error for these data is 0.05 °C; as such, it is impossible to distinguish between the years 2005 and 2010 on a statistical level.\nSource: Compiled by Earth Policy Institute from National Aeronautics and Space Administration (NASA), Goddard Institute for Space Studies (GISS), \"Global Land-Ocean Temperature Index in 0.01 degrees Celsius\" at http://data.giss.nasa.gov/gistemp/tabledata/GLB.Ts+dSST.txt, updated January 2011; Reto Ruedy, NASA GISS, e-mail to Alexandra Giese, Earth Policy Institute, 12 January 2010.

Source: https://www.quandl.com/EPI/74