A Minimal Book Example

Yihui Xie

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Contents

Chapter 1

Prerequisites

This is a *sample* book written in **Markdown**. You can use anything that Pandoc's Markdown supports, e.g., a math equation $a^2 + b^2 = c^2$.

The **bookdown** package can be installed from CRAN or Github:

```
install.packages("bookdown")
# or the development version
# devtools::install_github("rstudio/bookdown")
```

Remember each Rmd file contains one and only one chapter, and a chapter is defined by the first-level heading `#`.

To compile this example to PDF, you need XeLaTeX. You are recommended to install TinyTeX (which includes XeLaTeX): https://yihui.name/tinytex/.

Chapter 2

Introduction

You can label chapter and section titles using `{#label}` after them, e.g., we can reference Chapter 2. If you do not manually label them, there will be automatic labels anyway, e.g., Chapter 4.

Figures and tables with captions will be placed in `figure` and `table` environments, respectively.

```
par(mar = c(4, 4, .1, .1))
plot(pressure, type = 'b', pch = 19)
```

Reference a figure by its code chunk label with the `fig:` prefix, e.g., see Figure 2.1. Similarly, you can reference tables generated from `knitr::kable()`, e.g., see Table 2.1.

```
knitr::kable(
  head(iris, 20), caption = 'Here is a nice table!',
  booktabs = TRUE
)
```

You can write citations, too. For example, we are using the **bookdown** package (Xie, 2023) in this sample book, which was built on top of R Markdown and **knitr** (Xie, 2015).

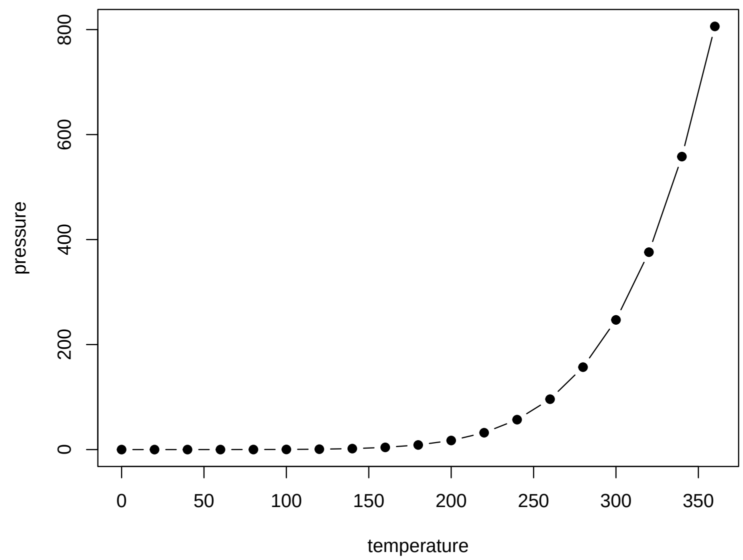


Figure 2.1: Here is a nice figure!

Table 2.1: Here is a nice table!

Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
5.1	3.5	1.4	0.2	setosa
4.9	3.0	1.4	0.2	setosa
4.7	3.2	1.3	0.2	setosa
4.6	3.1	1.5	0.2	setosa
5.0	3.6	1.4	0.2	setosa
5.4	3.9	1.7	0.4	setosa
4.6	3.4	1.4	0.3	setosa
5.0	3.4	1.5	0.2	setosa
4.4	2.9	1.4	0.2	setosa
4.9	3.1	1.5	0.1	setosa
5.4	3.7	1.5	0.2	setosa
4.8	3.4	1.6	0.2	setosa
4.8	3.0	1.4	0.1	setosa
4.3	3.0	1.1	0.1	setosa
5.8	4.0	1.2	0.2	setosa
5.7	4.4	1.5	0.4	setosa
5.4	3.9	1.3	0.4	setosa
5.1	3.5	1.4	0.3	setosa
5.7	3.8	1.7	0.3	setosa
5.1	3.8	1.5	0.3	setosa

Chapter 3

Literature

Here is a review of existing methods.

Chapter 4

Methods

We describe our methods in this chapter.

Math can be added in body using usual syntax like this

4.1 math example

p is unknown but expected to be around 1/3. Standard error will be approximated

$$SE = \sqrt(\frac{p(1-p)}{n}) \approx \sqrt{\frac{1/3(1-1/3)}{300}} = 0.027$$

You can also use math in footnotes like this[1].

We will approximate standard error to 0.027[2]

[1] where we mention $p = \frac{a}{b}$

[2] p is unknown but expected to be around 1/3. Standard error will be approximated

$$SE = \sqrt(\frac{p(1-p)}{n}) \approx \sqrt{\frac{1/3(1-1/3)}{300}} = 0.027$$

Chapter 5

Example

Load the *recharRge* library.

```
library(recharRge)
```

5.1 HydroBudget model

5.1.1 Input data and parameters

Load the input data for the simulation.

```
base_url <- "https://github.com/gwrecharge/rechaRge-book/raw/main/examples/input/"
input_rcn <- paste0(base_url, "rcn.csv.gz") # RCN values per RCN cell ID
input_climate <- paste0(base_url, "climate.csv.gz") # precipitation total in mm/d per climate cel
input_rcn_climate <- paste0(base_url, "rcn_climate.csv.gz") # relation between climate and RCN ce
input_rcn_gauging <- paste0(base_url, "rcn_gauging.csv.gz") # relation between gaugins station an
input_observed_flow <- paste0(base_url, "observed_flow.csv.gz") # flow rates in mm/d
input_alpha_lyne_hollick <- paste0(base_url, "alpha_lyne_hollick.csv.gz")
```

Set the **HydroBudget** model with the parameters values:

```
HB <- rechaRge::new_hydrobugdet(
  T_m = 2.1, # melting temperature (°C)
  C_m = 6.2, # melting coefficient (mm/°C/d)
  TT_F = -17.6, # Threshold temperature for soil frost (°C)
  F_T = 16.4, # Freezing time (d)
  t_API = 3.9, # Antecedent precipitation index time (d)
  f_runoff = 0.63, # Runoff factor (-)
```

```
  sw_m = 431, # Maximum soil water content (mm)
  f_inf = 0.07 # infiltration factor (-)
)
```

Set the column names mappings matching the input datasets:

```
HB$rcn_columns <- list(
  rcn_id = "cell_ID",
  RCNII = "RCNII",
  lon = "X_L93",
  lat = "Y_L93"
)
HB$climate_columns$climate_id <- "climate_cell"
HB$rcn_climate_columns <- list(
  climate_id = "climate_cell",
  rcn_id = "cell_ID"
)
HB$rcn_gauging_columns <- list(
  rcn_id = "cell_ID",
  station_id = "gauging_stat"
)
HB$alpha_lyne_hollick_columns$station_id <- "station"
```

Set the simulation period:

```
simul_period <- c(2010, 2017)
```

5.1.2 Simulation

Compute the water budget using the HydroBudget model:

```
water_budget <- recharge::compute_recharge(
  HB,
  rcn = input_rcn,
  climate = input_climate,
  rcn_climate = input_rcn_climate,
  period = simul_period
)
```

The water budget data set is per year-month in each RCN cell:

- `vi`, the vertical inflow
- `t_mean`, the mean temperature

- `runoff`, the runoff
- `pet`, the potential evapotranspiration
- `aet`, the actual evapotranspiration
- `gwr`, the ground water recharge
- `runoff_2`, the excess runoff

The head of this data set is:

year	month	vi	t_mean	runoff	pet	aet	gwr	runoff_2	delta_reservoir	rcn_id
2010	1	28.2	-7.3	21.5	1.6	1.6	10.2	0	-5.1	62097
2010	2	27.9	-5.7	7.9	4.6	4.6	8.8	0	6.6	62097
2010	3	83.0	1.0	30.8	19.5	19.5	16.1	0	16.6	62097
2010	4	68.2	7.7	24.9	51.5	51.5	15.1	0	-23.3	62097
2010	5	46.9	13.8	3.8	94.7	73.8	4.4	0	-35.2	62097
2010	6	107.9	17.0	33.3	114.7	81.1	0.2	0	-6.7	62097

5.1.3 Quality assessment

Process the river flow observations and assess simulation quality:

```
result <- rechaRge::compute_simulation_quality_assessment(
  HB,
  water_budget = water_budget,
  rcn_gauging = input_rcn_gauging,
  observed_flow = input_observed_flow,
  alpha_lyne_hollick = input_alpha_lyne_hollick,
  period = simul_period
)
```

5.1.4 Results handling

Save the simulation results:

```
sim_dir <- file.path(tempdir(), paste0("simulation_HydroBudget_", format(Sys.time(), "%Y%m%dT%H_%

# Write output files
# CSV
rechaRge::write_recharge_results(HB, water_budget, output_dir = sim_dir)
# NetCDF
rechaRge::write_recharge_results(HB, water_budget, output_dir = sim_dir, format = "nc", input_rcn
  "lon" = list(
    longname = "Qc lambert NAD83 epsg32198 Est",
    unit = "m"
  ),
```

```
  "lat" = list(
    longname = "Qc lambert NAD83 epsg32198 North",
    unit = "m"
  )
))
# Rasters
rechaRge::write_recharge_rasters(
  HB,
  water_budget = water_budget,
  input_rcn = input_rcn,
  crs = "+proj=lcc +lat_1=60 +lat_2=46 +lat_0=44 +lon_0=-68.5 +x_0=0 +y_0=0 +ellps=GRS8
  output_dir = sim_dir
)


# List simulation output files
list.files(sim_dir)
```

```
## [1] "bilan_spat_month.csv"         "bilan_unspat_month.csv"
## [3] "interannual_aet_NAD83.tif"    "interannual_gwr_NAD83.tif"
## [5] "interannual_runoff_NAD83.tif" "water_budget.nc"
```

5.1.5 Data visualization

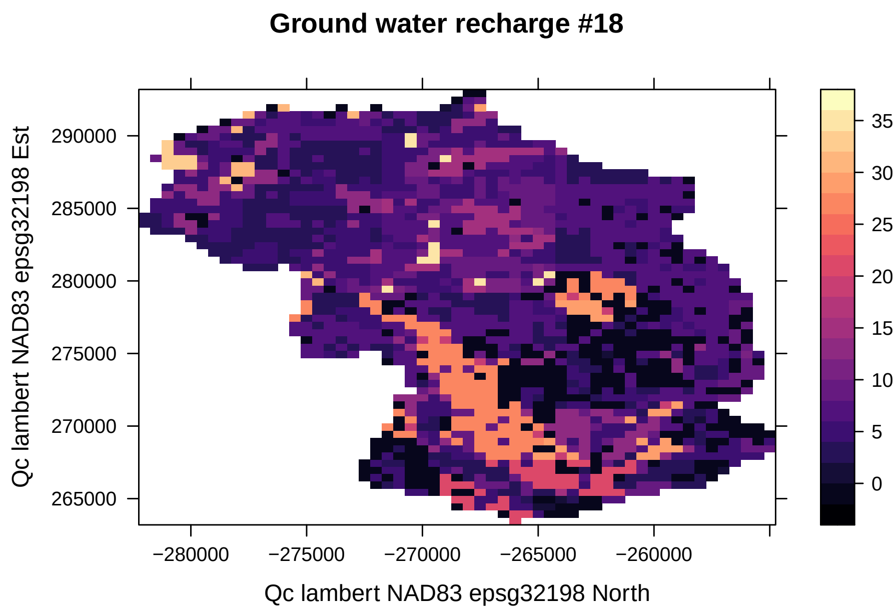
Visualize the saved NetCDF file:

```
library(ncdf4)
library(lattice)
library(viridisLite)

# Extract GWR data
nc <- nc_open(file.path(sim_dir, "water_budget.nc"))
gwr <- ncvar_get(nc, "gwr")
lon <- ncvar_get(nc, "lon")
lat <- ncvar_get(nc, "lat")
time <- ncvar_get(nc, "time")

# Render the 18th month
month <- 18
gwr1 <- gwr[,,month]
grid <- expand.grid(lon=lon, lat=lat)
title <- paste0(ncatt_get(nc, "gwr")$long_name, " #", month)
xlab <- ncatt_get(nc, "lat")$long_name
ylab <- ncatt_get(nc, "lon")$long_name
```

```
levelplot(gwr1 ~ lon * lat, data=grid, pretty=T, col.regions=magma(100),
          main=title, xlab=xlab, ylab=ylab)
```

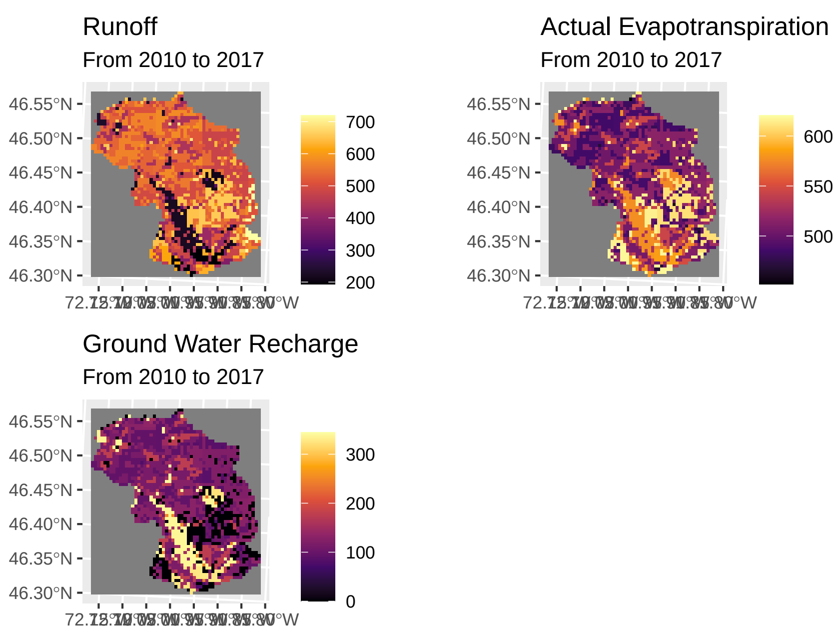



```
nc_close(nc)
```

Visualize the saved raster files:

```
library(tidyterra)
library(terra)
library(ggplot2)
library(cowplot)
subtitle <- ifelse(simul_period[1] == simul_period[2],
  paste0("In ", simul_period[1]),
  paste0("From ", simul_period[1], " to ", simul_period[2])
)
runoff <- terra::rast(file.path(sim_dir, "interannual_runoff_NAD83.tif"))
runoffplot <- ggplot() +
  geom_spatraster(data = runoff) +
  scale_fill_viridis_c(option = "inferno") +
  labs(
    fill = "",
    title = "Runoff",
    subtitle = subtitle
```

```
  )
aet <- terra::rast(file.path(sim_dir, "interannual_aet_NAD83.tif"))
aetplot <- ggplot() +
  geom_spatraster(data = aet) +
  scale_fill_viridis_c(option = "inferno") +
  labs(
    fill = "",
    title = "Actual Evapotranspiration",
    subtitle = subtitle
  )
gwr <- terra::rast(file.path(sim_dir, "interannual_gwr_NAD83.tif"))
gwrplot <- ggplot() +
  geom_spatraster(data = gwr) +
  scale_fill_viridis_c(option = "inferno") +
  labs(
    fill = "",
    title = "Ground Water Recharge",
    subtitle = subtitle
  )
cowplot::plot_grid(runoffplot, aetplot, gwrplot)
```



Chapter 6

Final Words

We have finished a nice book.

Bibliography

Xie, Y. (2015). *Dynamic Documents with R and knitr*. Chapman and Hall/CRC, Boca Raton, Florida, 2nd edition. ISBN 978-1498716963.

Xie, Y. (2023). *bookdown: Authoring Books and Technical Documents with R Markdown*. R package version 0.37, https://pkgs.rstudio.com/bookdown/.