The R Package Management System: Bayesian Change Point Analysis

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I would like to thank Chandra Erdman (Yale GRD ’08) for her collaboration on the Bayesian change point analysis and package **bcp**. Chandra is now at the Census Bureau.

Please feel free to ask questions along the way!

http://www.stat.yale.edu/~jay/Brazil/Campinas/bcpANDpackages/
http://www.stat.yale.edu/~jay/RPC

Outline

Why R?

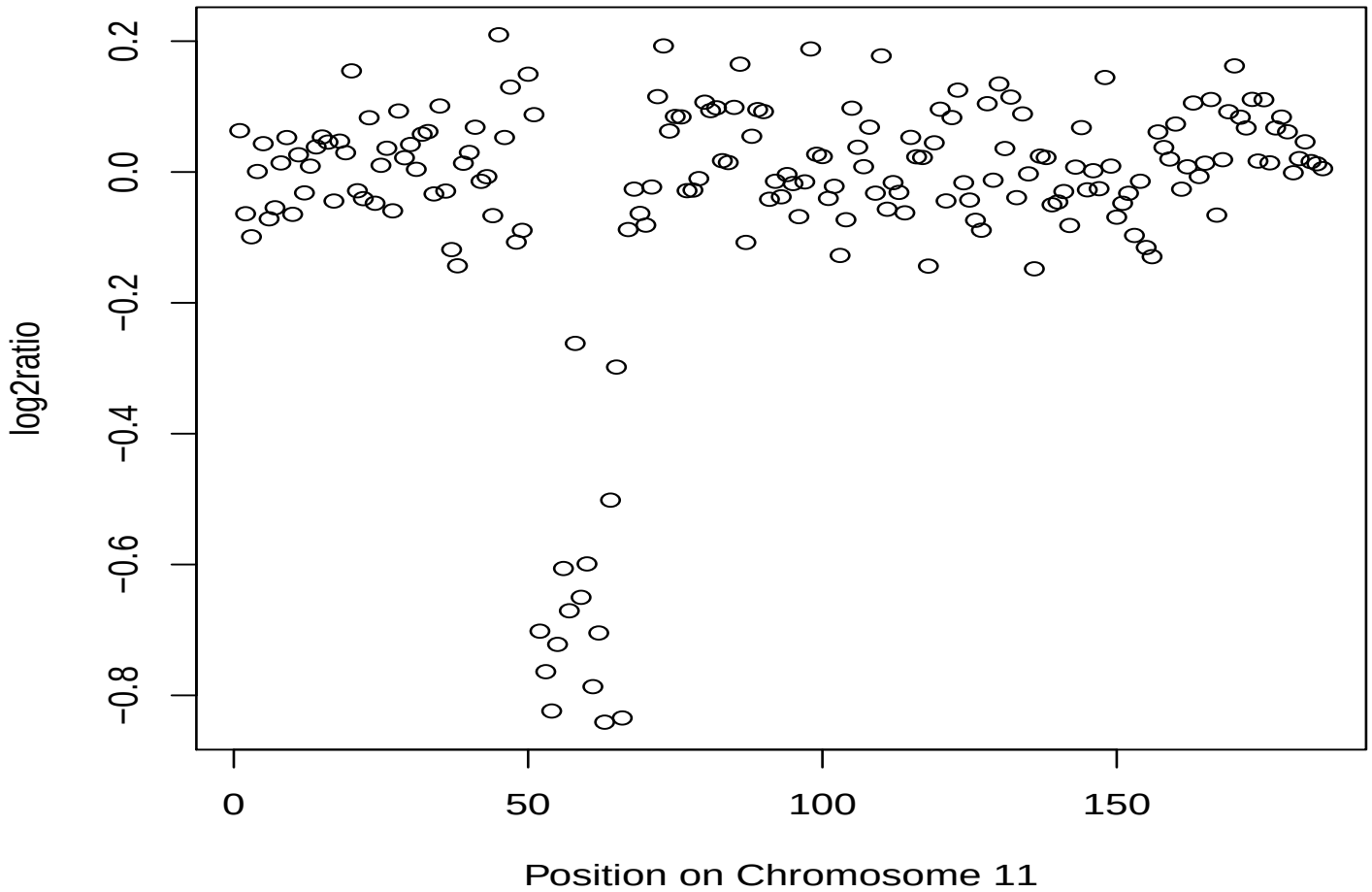
R is the *lingua franca* of statistics:

- The syntax is simple and well-suited for data exploration and analysis.
- It has excellent graphical capabilities.
- It is extensible, with over 2500 packages available on CRAN alone.
- It is open source and freely available for Windows/MacOS/Linux platforms.

This talk emphasizes the importance of the package management system. Much of the success of R should be attributed to:

- Ross & Robert's early decision to go open-source and encourage collaboration, and
- the growth of CRAN and the success of the package management system.

Example: Coriell cell lines (raw data)

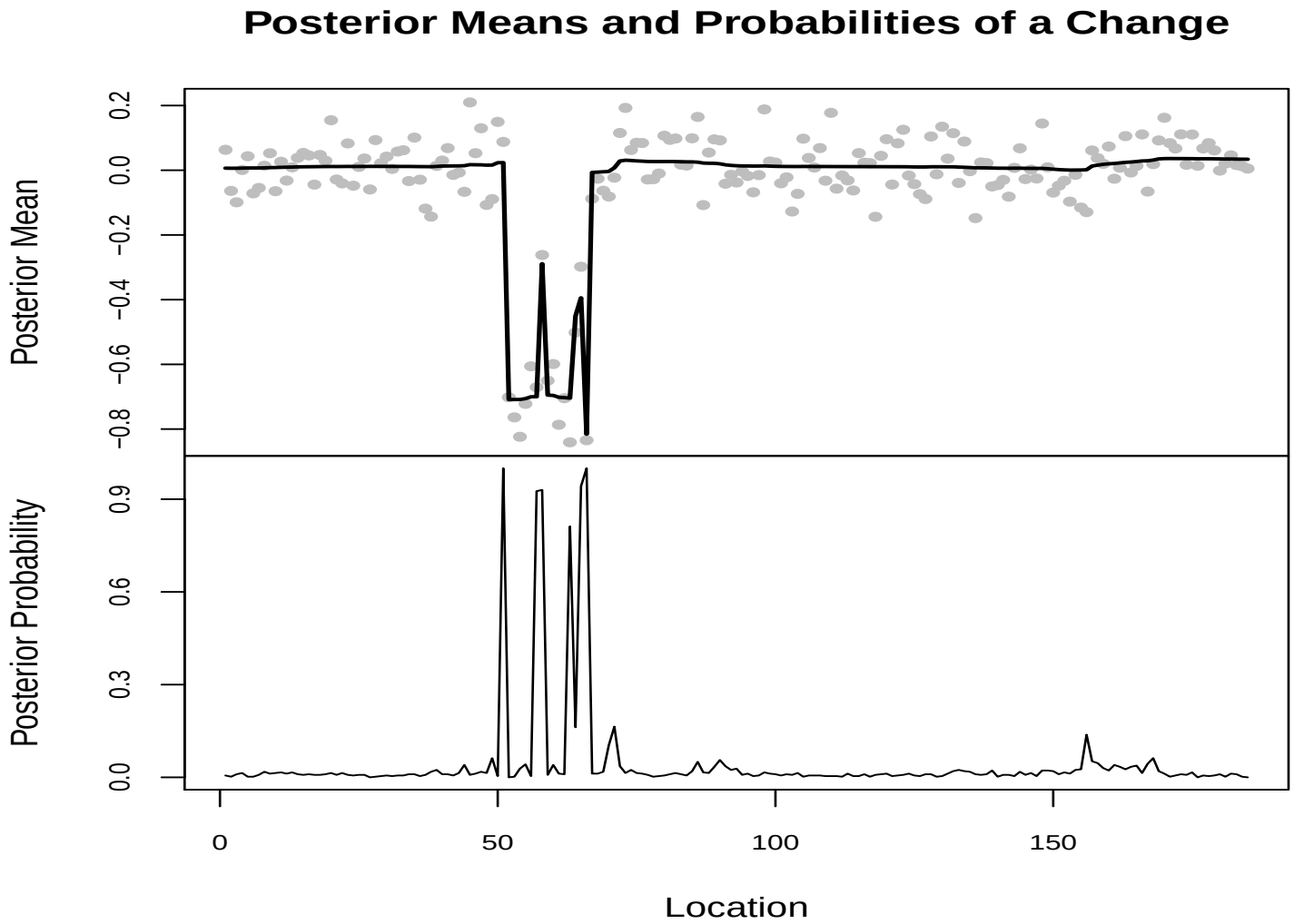


Example: Coriell cell lines (bcp analysis)

See `http://cran.r-project.org/web/packages/bcp/`.

```
> library(bcp)
> data(coriell)
>
> chrom11 <- as.vector(na.omit(
+                 coriell$Coriell.05296[
+                   coriell$Chromosome == 11]))
>
> bcp.11 <- bcp(chrom11)
> plot(bcp.11)
```

Example: Coriell cell lines (bcp output)



The Bayesian change point model

ρ unknown partition into continuous blocks, with the transition between blocks being the "change points."

p probability of a change point at position i, independently for all i.

X_i observations assumed independent $N(\mu_i, \sigma^2)$, where in this notation the μ_i are equal for all i within a block.

μ_{jk} mean of block from position $j+1$ to k, with prior $N(\mu_0, \sigma_0^2/(k-j))$. Note: larger deviations from μ_0 are expected for shorter blocks, but weak signals can be detected when sufficient data are available.

w defined as $\sigma^2/(\sigma^2+\sigma_0^2)$ for convenience.

Possible point of notational confusion: conditional on ρ (the partition into blocks), $\mu_i \equiv \mu_{jk}$ for all i in block jk.

The Bayesian change point priors

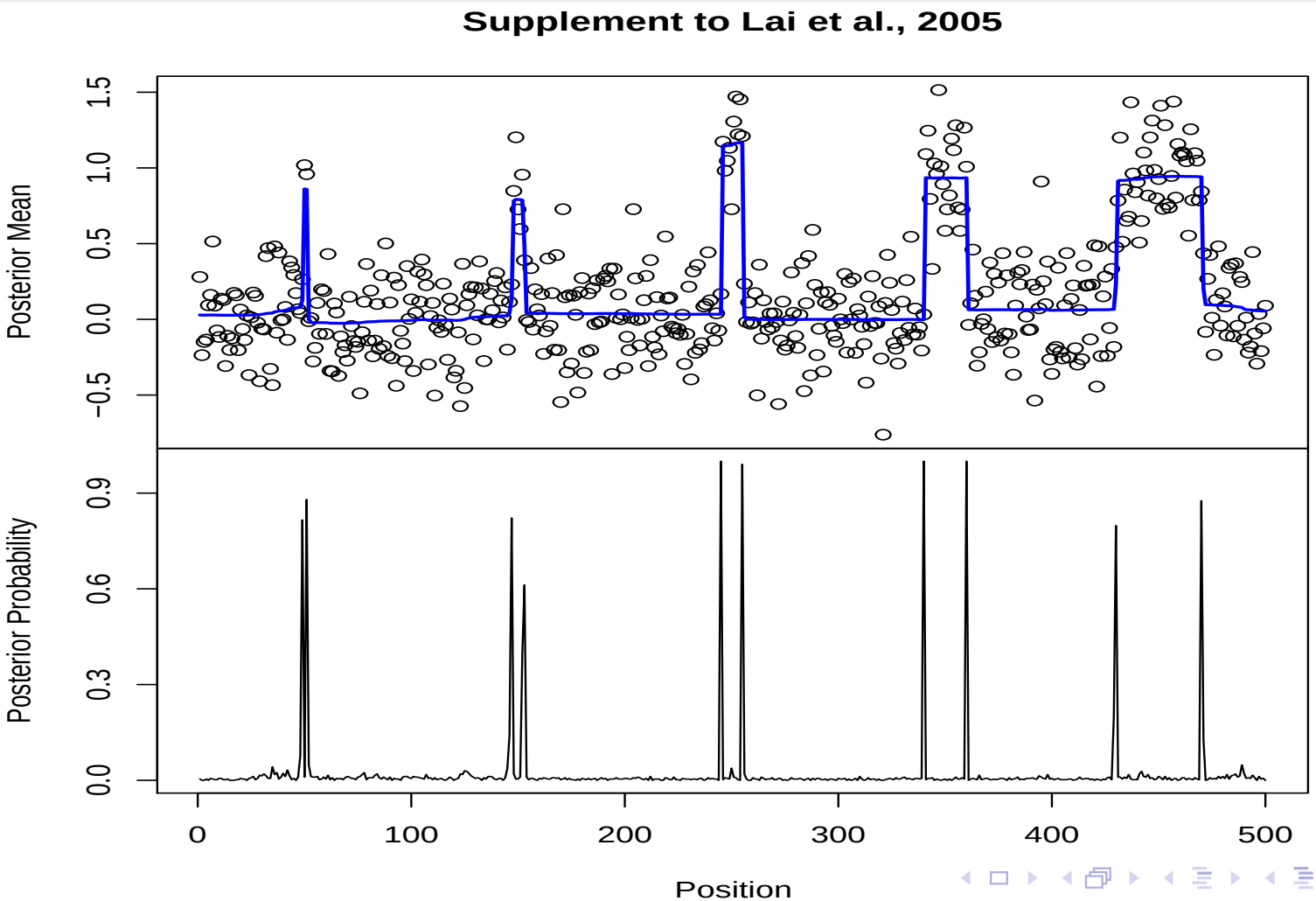
$$\begin{aligned}
\pi(\mu_0) &= 1, \quad -\infty \leq \mu_0 \leq \infty \\
\pi(\sigma^2) &= 1/\sigma^2, \quad 0 \leq \sigma^2 \leq \infty \\
\pi(p) &= 1/p_0, \quad 0 \leq p \leq p_0 \\
\pi(w) &= 1/w_0, \quad 0 \leq w \leq w_0 \\
\pi(\rho) &= \frac{1}{p_0}\left[\int_0^{p_0} p^{b-1}(1-p)^{n-b}\, dp\right]
\end{aligned}$$

where p_0 and w_0 are pre-selected in $[0, 1]$ (values of 0.2 are the default in package **bcp** and work well in a wide range of cases), and b is the number of blocks in ρ.

Notes on Bayesian change point analysis

- Barry and Hartigan (1993): "A Bayesian analysis for change point problems" in *JASA*, 88, 309-319.
- Erdman and Emerson (2008): "A fast Bayesian change point analysis for the segmentation of microarray data" in *Bioinformatics*, 24 (19), 2143-2148.
- Erdman and Emerson (2007): "bcp: an R package for performing a Bayesian analysis of change point problems" in *JSS*, 23 (3).
- An exact implementation of the Bayes procedure is possible but the calculations would be $O(n^3)$.
- Package **bcp** provides a fast $O(n)$ MCMC implementation:
  - inefficient MCMC would be $O(n^2)$
  - solves some nasty numerical problems with large data
  - supports parallel MCMC
  - currently being extended for multivariate series with a common change point structure

Second example: simulated abberations of length 2, 5, 10, 20, and 40



Building an R build environment

If you want to build R packages, you'll need the full R build environment (not just the pre-compiled R binary that most of us use from CRAN). See

`http://www.stat.yale.edu/~jay/RPC/RPackages.pdf`

A simple package: function babywhatis()

```
> ls()
[1] "bcp.11"  "chrom11" "coriell"
> rm(list = ls())
> ls()
character(0)
> babywhatis <- function(x) {
+     if (!is.data.frame(x)) {
+         x <- data.frame(x)
+         warning("Object coerced to a data frame.\n")
+     }
+     return(unlist(lapply(x, class)))
+ }
> ls()
[1] "babywhatis"
```

A simple package: the package skeleton

```
> package.skeleton("MyToolkit")

Creating directories ...
Creating DESCRIPTION ...
Creating Read-and-delete-me ...
Saving functions and data ...
Making help files ...
Done.
Further steps are described in
  './MyToolkit/Read-and-delete-me'.
```

Let's go investigate together; we'll explore the package structure, make minor modifications, and will check/build/install it. More information is available in

`http://www.stat.yale.edu/~jay/RPC/RPackages.pdf`

Package bcp

At this point, we'll just glance at package **bcp** quickly. I want to introduce the C/C++ interface with a simple example before looking more closely at **bcp**.

A simple example: column minima

This material wouldn't display well in slides. Again see

`http://www.stat.yale.edu/~jay/RPC/RPackages.pdf`

and, specifically, materials in

`http://www.stat.yale.edu/~jay/RPC/MyToolkitWithC/`

Package bcp

Package **bcp** uses the `.C()` interface instead of `.Call()`, though I'd like to change this in a new version.

foreach

The user may register any one of several “parallel backends” like **doMC** or **doSNOW**, or none at all. The code will either run sequentially or will make use of the parallel backend, if specified, without code modification.

```
> library(foreach)
> library(doMC)
> registerDoMC(2)
>
> a <- 10
> ans <- foreach(i = 1:5, .combine = c) %dopar%
+     {
+         a + i^2
+     }
>
> ans
[1]  11  14  19  26  35
```

Parallel MCMC in package bcp

- An older version of **bcp** used **NetWorkSpaces** for parallel MCMC; this was very difficult to install and use, and the code was not portable to other parallel environments.
- The new **bcp** uses Steve Weston's **foreach** package, and the user may choose from a variety of parallel backends.
- I strongly recommend `foreach()` for parallel programming, to both users and package developers.
- Again, see supplementary materials for more information.

Thanks

- Bell Laboratories (Rick Becker, John Chambers and Allan Wilks), for development of the S language
- Ross Ihaka and Robert Gentleman, for their work and unselfish vision for R
- The R Core team
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- John Emerson (my father, Middlebury College), for getting me started in statistics and computer science
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