Earth, Atmospheric & Planetary Sciences

EarthScope Consortium

Working with command-line systems and GAMIT/GLOBK

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GNSS Data Processing and Analysis with GAMIT/GLOBK and `track`

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Material from R. W. King, T. A. Herring, M. A. Floyd (MIT) and S. C. McClusky (now at ANU)

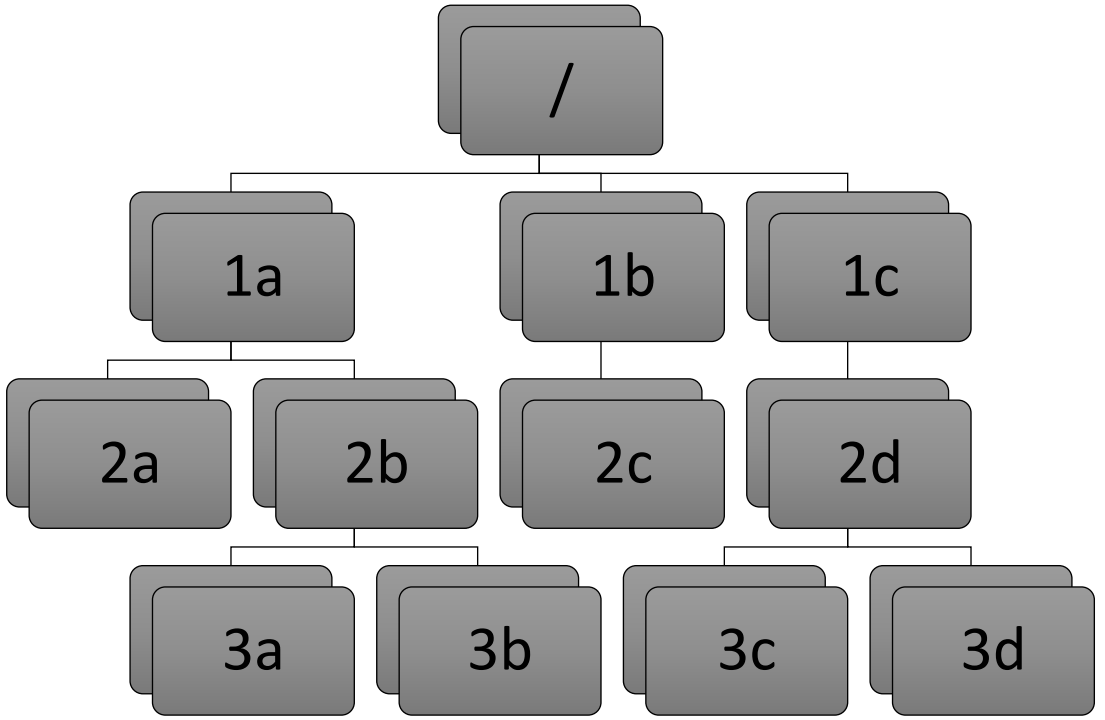
Introduction to command-line computing

- Directory structure and navigation
- Using a command line
- Commands to know
- Introduction to shell scripts

Directory structure and navigation

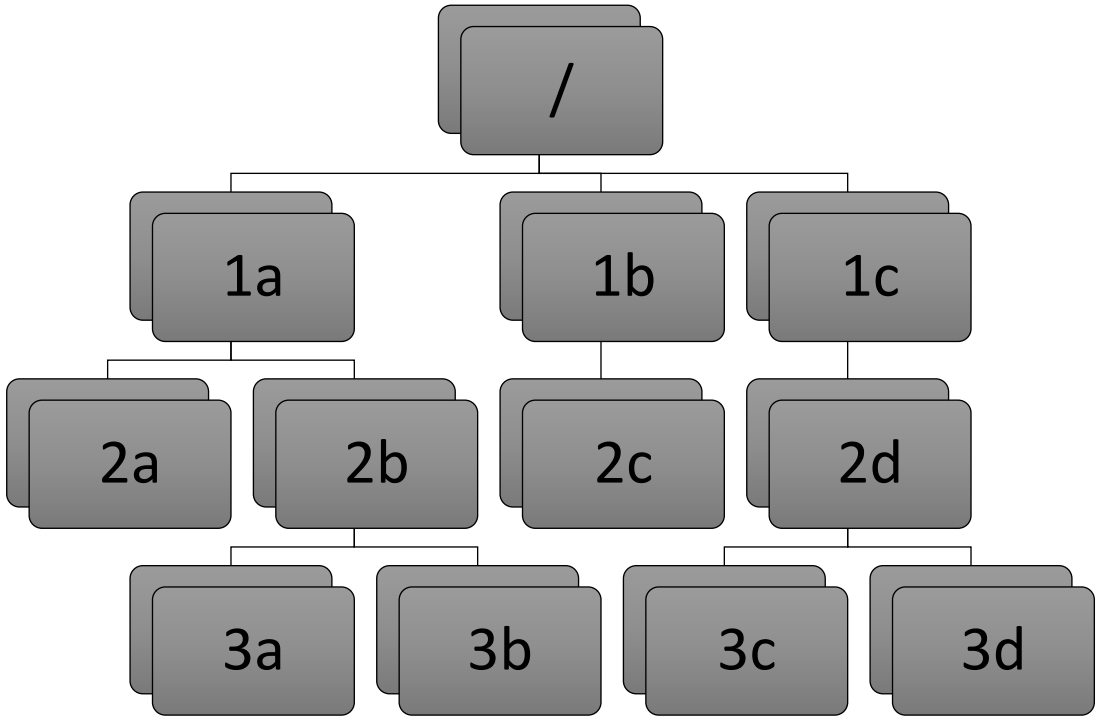
Directory structures

- One must be familiar with the layout of files and directories (or “folders”)
- Once one has a mental “map” of the directory structure, navigating between directories and finding files is easier
- Think of it as a filing cabinet or family tree



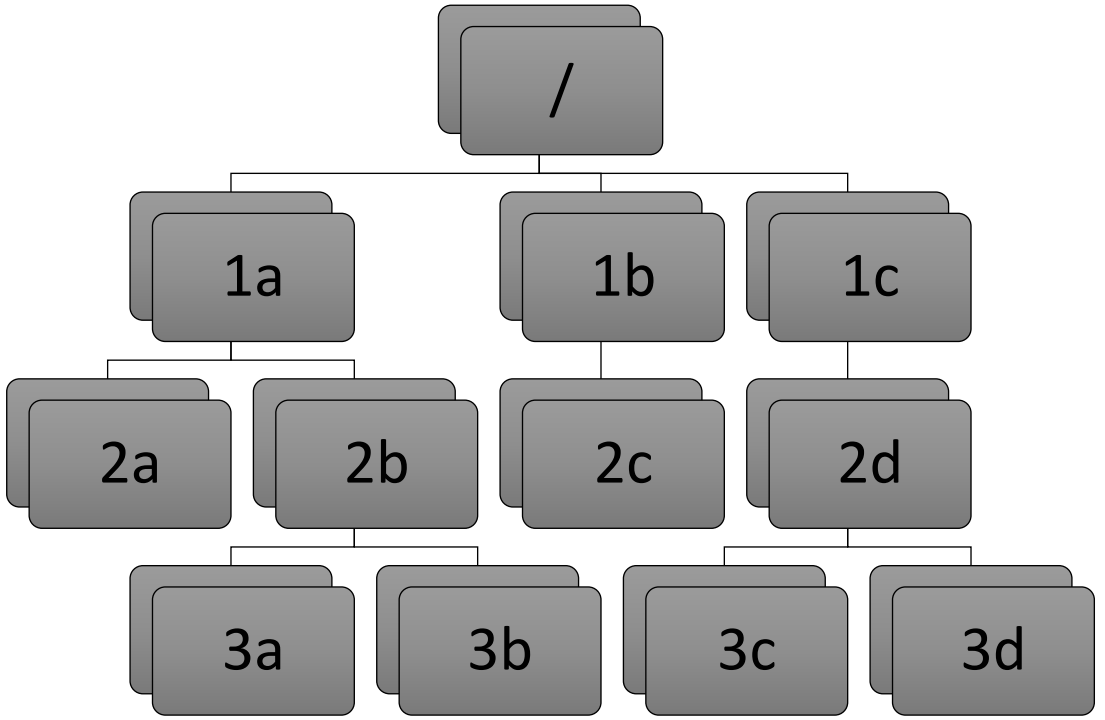
Directory structures

- Top-level (“root”) directory (e.g. “/” on Unix, “C:\” on Windows, etc.)
- User’s current working directory is referred to by the shorthand “.” [dot]
- The “parent” directory is one level above the current working directory in the hierarchy
- Parent directory is referred to by the shorthand “..” [double dot]



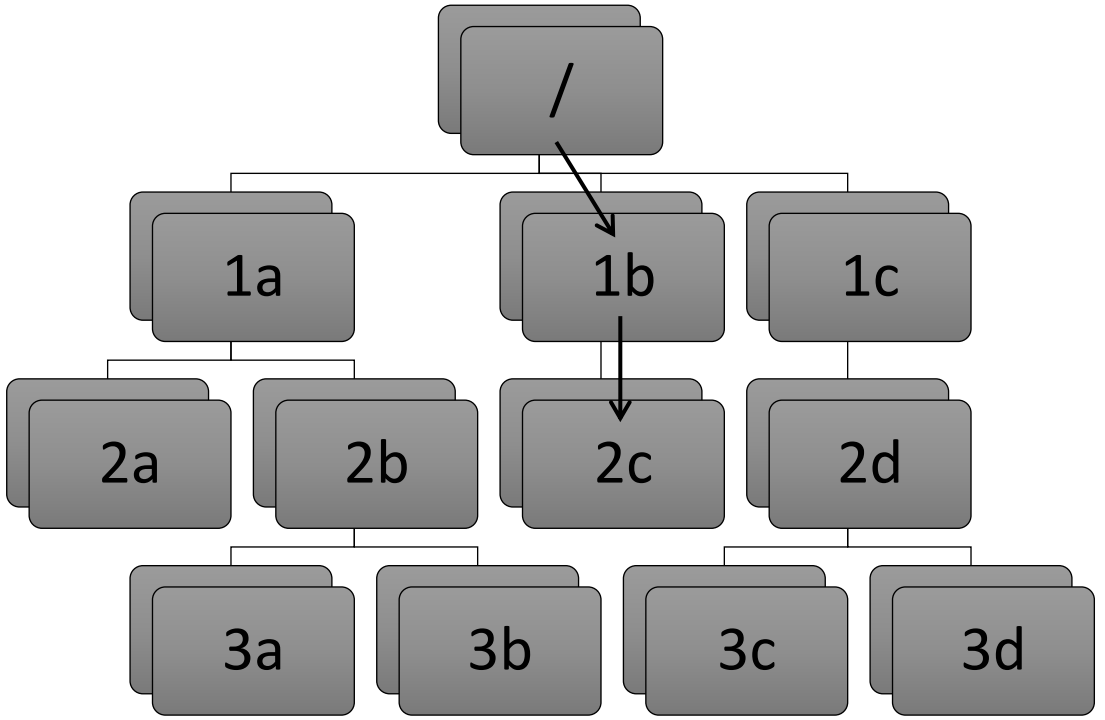
Changing directory

- Once user knows where they are with “mental map” of directory structure, move around. We can move up or down the hierarchy but not sideways.
- `cd /`
  - Takes user to top-level (“root”) directory
- `cd 1b`
  - Takes user to “1b” directory in first level (move down hierarchy)
- `cd 2c`
  - Takes user to “2c” directory in second level, below “1b” (move down hierarchy)
- `cd 2d`
  - Unknown directory. Why?
  - User attempting to move sideways but “2c” not connected directly to “2d”.



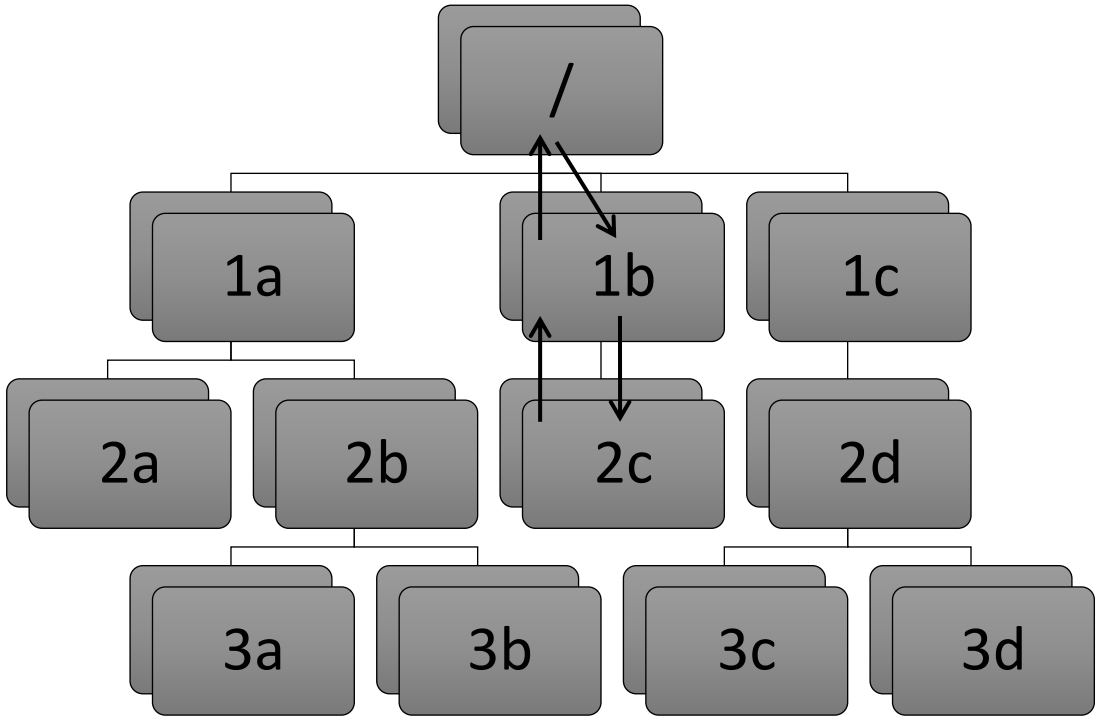
Absolute paths

- To move back up the hierarchy to “2d”, one may explicitly start from the top level, e.g.
- `cd /`
- `cd 1c`
- `cd 2d`
- or, combined, simply
- `cd /1c/2d`
  - Directories are separated by forward slashes



Relative paths

- Or:
- Move back up to “1b”
  - `cd ..`
- Move back up to “/”
  - `cd ..`
- Move down to “1c”
  - `cd 1c`
- Move down to “2d”
  - `cd 2d`
- Or, combined, simply:
  - `cd ../../1c/2d`



Using a command line

Using a command line

- Basic syntax is:
  `<command> <options> <argument(s)>`
- `<command>` is the program to run, including directory if not included in PATH environment variable (more in a couple of slides…)
- `<options>` are usually prepended by a dash (e.g. `-a`)
- `<argument(s)>` are usually input or output files to work on
- Commands may or may not have options or expect arguments

Basic commands

- `cd`
  - Change directory, for navigating the directory structure
- `pwd`
  - Print working directory, to know where you are
- `ls`
  - List directories and files in current working directory (“.”) or directory given after command
- Use the “tab” key to auto-complete options

Environment variables

- A computer must be told information in order to work the way you expect
- Many important settings are kept in “environment variables”
  - $HOME = user’s home directory
  - $PATH = list of directories containing programs
  - $SHELL = user’s command shell
- `printenv`
  - Prints information on environment variables

Local variables

- To make life easier, one may also set local variables, which may be referred back to at any time
- Useful if one finds the need to write the same thing many times
- sh/bash:
  - `var='Hello'`
  - Instead of writing “Hello”, any reference to $var will be equivalent to “Hello”
  - `var=( Hello Goodbye )`
  - Any reference to ${var[0]} will be equivalent to “Hello” and ${var[1]} to “Goodbye”
- csh/tcsh:
  - `set var = 'Hello'`
  - Instead of writing “Hello”, any reference to $var will be equivalent to “Hello”
  - `set var = ( Hello Goodbye )`
  - Any reference to $var[1] will be equivalent to “Hello” and $var[2] to “Goodbye”

Commands to know

Everyday commands

- `awk`
- `grep`
- `sed`
- `sort`
- `paste/join`
- `tr`
- `echo/cat`

awk

- Powerful formatted read/write utility, e.g.
- `awk '{print $1,$2,$3}' <file>`
  - Prints first, second and third white-spaced columns (“fields”) from each line of <file>
- `awk -v n=3 -v FS=',' '{print $NF/n}' <csv-file>`
  - Prints the last comma-separated field divided by 3 from each line of <csv-file>
- `awk 'BEGIN {sum=0}; {sum=sum+$1}; END {printf "%.1f\n",sum/NR}' <file>`
  - Calculate mean of first field: sums first field on each line then divides by number of lines (“records”)

grep

- Pattern-matching command (“general regular expression”)
- `grep 'hello' <file>`
  - Prints all lines from <file> with occurrence of “hello” in them
- `grep –ci '^POS S' <file>`
  - Prints the number (“-c”) of lines that begin (“^”) with “POS S” in either upper- or lower-case letters (“-i”) in <file>
- `grep '^ .* P$' <file>`
  - Print all lines in <file> that begin (“^”) with a space, followed by any number of any characters (“.*”), and end (“$”) with a space followed by P

sed

- Basic text editor
- `sed 's/ //g' <file>`
  - Substitute (“s”) all (“g”) instances of a single whitespace with nothing (i.e. delete all whitespace)
- `sed '/^ *$/d; s/hello/goodbye/1' <file>`
  - Delete (“d”) all empty lines and substitute the first instance of “hello” with “goodbye” on each line of <file>

sort

- Sorts records
- `sort <file>`
  - Outputs basic alpha-numerically ordered <file>
- `sort -u <file>`
  - Same as above but uniquely sorted (i.e. removes duplicate records)
- `sort -g -k 3 <file>`
  - General numeric ordering based on third field of <file>
- `sort -u -k 2.1,2.4 <file>`
  - Sort based on first character of second field to fourth character of second field and use this as the basis for the uniqueness test

`tr`

- Basic translation
- `tr '[:upper:]' '[:lower:]'`
  - Transposes all upper-case letters to lower-case
- `tr -d '\r'`
  - Deletes all carriage return (“CR”) characters (useful for changing a file’s line ending from DOS to UNIX format)

echo/printf/cat

- Echoes the argument
- `echo 'Help!'`
  - Prints “Help!”
- `printf 'Help!\n'`
  - Prints a formatted string
- `cat <file>`
  - Reads out entirety of <file>
- `cat << END`

```
Help!
END
```

  - Same as “`echo 'Help!'`” and “`printf 'Help!\n'`”

Redirection

- The output from one command may be written to a file…
  - “>” to overwrite an existing file
  - “>>” to append to an existing file
  - `sort [file] > [sorted file]`
- …or “piped” to another command, effectively forming the second command’s input
  - “|”
  - `grep '^ .* P$' [file] | sort > [grep’d and sorted file]`

Shorthands

- Top-level (“root”) directory = “/”, e.g.
  - `cd /`
- Your home directory = “~” or “$HOME”, e.g.
  - `ls ~`
- “Links” or “shortcuts” may be created, e.g.
  - `ln -s /home/user/gg/10.71 ~/gg`
- This creates a link in the user’s home directory called “gg” that points to the directory /home/user/gg/10.71
  - Rather than “`cd /home/user/gg/10.71`”, one can get to the same place simply with “`cd ~/gg`”
  - (This is used in GAMIT/GLOBK scripts and must remain in place!)

Useful commands

- `du`
  - Disk usage: useful if you want to know how much space your (or others'!) directories are taking up
- `df`
  - Disk free space: useful if you want to know how much disk space is used and free
- `top`
  - Table Of Processes: useful if you want a real-time overview of processes that are running
- `ps`
  - List processes: useful if you want to see what processes are running and their process numbers, commands, etc.

Introduction to shell scripts

What is a script?

- Scripts contain a series of commands written in one file and prepended by a “hash-bang”
  - `#!/bin/sh` for original Bourne Shell (usually the same as bash on modern systems)
  - `#!/bin/bash` for Bourne Again Shell
  - `#!/bin/csh` for C Shell (usually the same as tcsh on modern systems)
  - `#!/bin/tcsh` for TENEX C Shell
- The script may then be executed to run all of the commands in sequence as written
- Most scripts in GAMIT/GLOBK are written in csh or tcsh; many newer scripts are written in bash
  - Must have both csh and tcsh installed to run GAMIT/GLOBK scripts
  - bash usually installed by default on current Linux distributions

Script example

```
#!/bin/bash
printf 'The ISO date is: '
date '+%Y-%m-%dT%H:%M:%S%Z'
printf 'The mean of all numbers between 1 and 10 is: '
echo 1 10 | awk 'BEGIN {sum=0; n=0}; {for (i=$1; i<=$2; i++) {sum=sum+i; n++}}; END {print sum/n}'
printf 'Goodbye!\n'
```

Installing GAMIT/GLOBK

Sources of prerequisite information

- http://geoweb.mit.edu/gg/pre.php
- http://geoweb.mit.edu/gg/docs/GG_Quick_Start_Guide.pdf
- http://geoweb.mit.edu/~floyd/computing/mac/gfortran/
- http://geoweb.mit.edu/~floyd/computing/mac/gv/

Separation of tasks

- Source code directory
- Installation directory
- Processing directory

Source code directory (optional)

Source code directory

- Users may wish to keep a local copy of source code
  - As backup in case of problems during installation
  - If unable to reconnect to the source code repository (https://chandler.mit.edu/gps/)
- If you wish to do this, keep it separate from where you intend to install GAMIT/GLOBK, e.g.
  - ~/src/gg/10.71
  - ~/Applications/src/gg/10.71

Main installation directory

Main installation directory

- Choose a suitable directory for installing the software
  - Suggested place in home directory, e.g. ~/src/gg, ~/Programs/gg, etc. (for example, I install GG version 10.71 in /Users/maf/Applications/gg/10.71)
  - Alternative may be your /usr/local directory, e.g. /usr/local/gg/10.71 but you must have administrator permissions
  - Take great care not to mix source versions, e.g. 10.70 versus 10.71
- Change to this directory to download (or copy) the source code
- This will be the directory that is ultimately linked from your home directory (~/gg)

Downloading source via FTP

FTP server (soon to be deprecated)

- chandler.mit.edu/updates/
  - username: guest
  - password: [changeable]
- Use curl or wget or an FTP client, such as ftp or ncftp
- Internet browsers generally do not allow connection to FTP domains nowadays, e.g.
  - ftp://guest@chandler.mit.edu/updates/

HTTP server (now preferred)

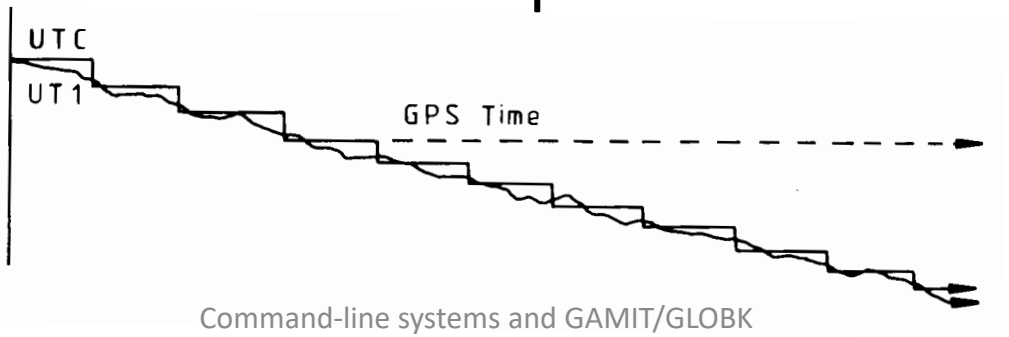
- https://chandler.mit.edu/gps/
  - username: guest
  - password: [changeable]
- Use curl or wget or another preferred client

Source code

- Change directory to source/
- Need at least:
  - com
  - gamit
  - help
  - kf
  - libraries
  - tables
  - incremental_updates (if any)
- Also download install_software
- Depending on your processing strategy, may also need to download grids (e.g. ocean-tide loading, atmospheric loading grids, etc.) from ftp://everest.mit.edu/pub/GRIDS/ to a local ~/gg/GRIDS/ directory

Updates!

- Incremental updates are made available approximately every month, so please check at least
  - Earth orientation parameters (pole.* and ut1.*; or sh_update_eop)
  - SVN-PRN translation tables (svnav.dat)
  - Differential code biases (dcb.dat)
  - Leap seconds (leap.sec)
  - Loading grids (ftp://everest.mit.edu/pub/GRIDS/)
- Example: 2016-12-31T23:59:60Z leap second



Documentation

- Top-level “README” file at ftp://guest@chandler.mit.edu/updates/README
- Change directory to updates/documentation/
  - GAMIT/GLOBK prerequisites in GAMIT_prerequisites.pdf
    http://geoweb.mit.edu/gg/pre.php
    https://guest@chandler.mit.edu/gps/documentation/GAMIT_prerequisites.pdf
  - Quick Start Guide in GG_Quick_Start_Guide.pdf
    http://geoweb.mit.edu/gg/docs/GG_Quick_Start_Guide.pdf
  - Introductory GPS material in Intro_GG.pdf
    http://geoweb.mit.edu/gg/docs/Intro_GG.pdf
    https://guest@chandler.mit.edu/gps/documentation/Intro_GG.pdf
  - GAMIT reference manual in GAMIT_Ref.pdf
    http://geoweb.mit.edu/gg/docs/GAMIT_Ref.pdf
    https://guest@chandler.mit.edu/gps/documentation/GAMIT_Ref.pdf
  - GLOBK reference manual in GLOBK_Ref.pdf
    http://geoweb.mit.edu/gg/docs/GLOBK_Ref.pdf
    https://guest@chandler.mit.edu/gps/documentation/GLOBK_Ref.pdf

Compiling GAMIT/GLOBK

Required tools

- Depending on your system, a number of programs may need to be added. One needs:
- A Fortran code compiler (e.g. gfortran)
- A C code compiler (e.g. gcc or clang on macOS)
- X11 libraries and headers, specifically:
  - libX11.a, libX11.so, libX11.dylib, libX11.la or libX11.dll.a (depending on your system)
  - Xlib.h
- Linux
  - Be sure a C-shell (csh and tcsh) is installed (this is not the case by default with Ubuntu, for instance)
  - X11 libraries and headers may also need to be installed
- Mac
  - Download the latest “Command Line Tools” (Mac OS X 10.7.3 or later)
  - X11 was replaced by XQuartz (https://www.xquartz.org/) for Mac OS X 10.8 (Mountain Lion) and later
- Windows
  - Ubuntu on VirtualBox or VMWare virtual machine (or Windows Subsystem for Linux on recent versions of Windows 10):
    `sudo apt install gfortran make libx11-devel csh tcsh bc`
  - Cygwin: Devel/make; Math/bc; Shells/tcsh; X11/libX11 (or X11/xinit)

Notes on known problems

- Very new gfortran releases, especially those with a version number ending in 0 (e.g. 4.9.0), sometimes are buggy and produce compilation problems
  - If this is the case, try compiling a program using only the “-O3” flag or revert to an older, stable version of gfortran
- Currently running gfortran 8.2.0 on laptop with macOS 10.15 (Catalina) and 4.6.3, 4.8.4 or 7.5.0 on MIT computers with Ubuntu Linux
- See http://geoweb.mit.edu/gg/issues.php

Running `install_software`

- From the main installation directory, where the source tar-files and install_software should be copied
- Run `./install_software`
- As you pass through the installation process, please read the questions, e.g.

```
Searching directories set in libraries/Makefile.config for
X11 installation
Verified these paths to X11 libs and includes
X11LIBPATH:
X11INCPATH:
Are these paths complete and correct for your system?
(y/n)
```

- If they are not correct, say “n” then install_software will search or exit and one can then edit libraries/Makefile.config appropriately

A note here on permissions

- A computer may read (“r”), write (“w”) and/or execute (“x”) a directory or file
- Each action may be allowed by a user (“u”), group (“g”) or others (“o”)
- A computer must follow instructions, called “permissions”, on if it allowed to do any or all of these for any
- Any file that you want to run as a program must be made “executable”
  - `chmod a+x <file>`
  - Change moderations (permissions) so executable (“x”) permissions are added to <file> for all (“ugo”)
- You may find you need to verify that directories and files are readable, writable and/or executable as necessary throughout your UNIX experience

Potentially necessary edits

- libraries/Makefile.config is the main control file for the installation process
- Check:
  - X11LIBPATH (path to libX11)
  - X11INCPATH (path to Xlib.h)
  - MAXSIT (max. number of sites to process simultaneously)
  - MAXSAT (do not change)
  - MAXATM (max. atmospheric estimates per session)
  - MAXEPC (max. epochs per session, e.g. 24 hours at 30 s interval = 2880 measurement epochs)
  - OS block (usually no need to change)

Setting environment variables

- sh/bash (e.g. in ~/.bash_profile, ~/.bashrc or ~/.profile):

```
gg=‘/Users/maf/Programs/gg/10.71’
PATH="$gg/com:$gg/gamit/bin:$gg/kf/bin:$PATH"; export
PATH
HELP_DIR="$gg/help/"; export HELP_DIR
INSTITUTE=‘MIT’; export INSTITUTE
```

- csh/tcsh (e.g. in ~/.cshrc):

```
set gg = ‘/Users/maf/Programs/gg/10.71’
setenv PATH "$gg/com:$gg/gamit/bin:$gg/kf/bin:$PATH"
setenv HELP_DIR "$gg/help/"
setenv INSTITUTE ‘MIT’
```

Additional environment variables

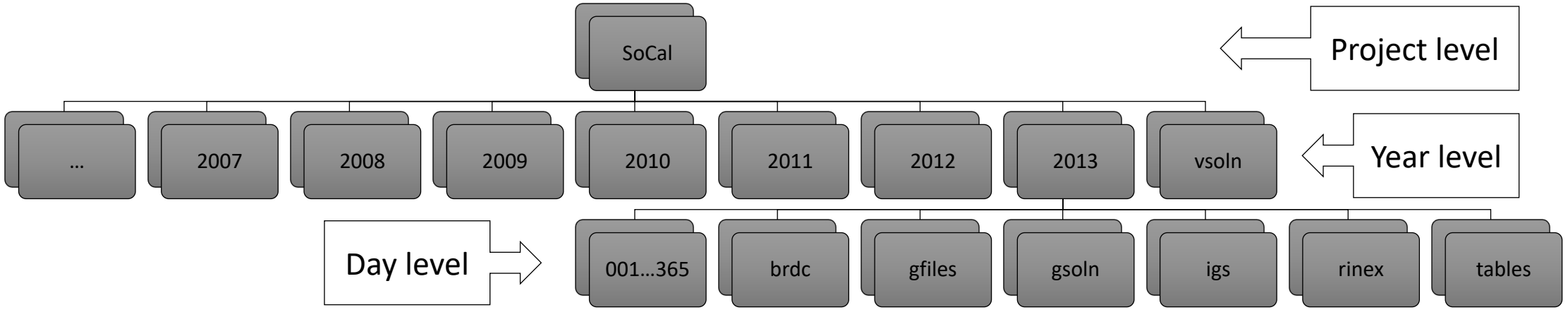
- Some locales (your computer's language and numbers setting) use a comma for the decimal separator rather than a point, e.g. "1000.00" versus "1000,00" for one thousand to two decimal places
- This is typical in many languages other than English
- Using this scheme breaks certain GAMIT/GLOBK scripts that perform basic numeric calculations while formatting data, as well as GMT
- To avoid this problem without having to change your language, set the "LC_NUMERIC" environment variable to "C" or an appropriate language locale, e.g. "en_GB.UTF-8" or "en_US.UTF-8"
  - sh/bash (e.g. in ~/.bash_profile, ~/.bashrc or ~/.profile):
    ```
    LC_NUMERIC='C'; export LC_NUMERIC
    ```
  - csh/tcsh (e.g. in ~/.cshrc):
    ```
    setenv LC_NUMERIC 'C'
    ```

Processing directories

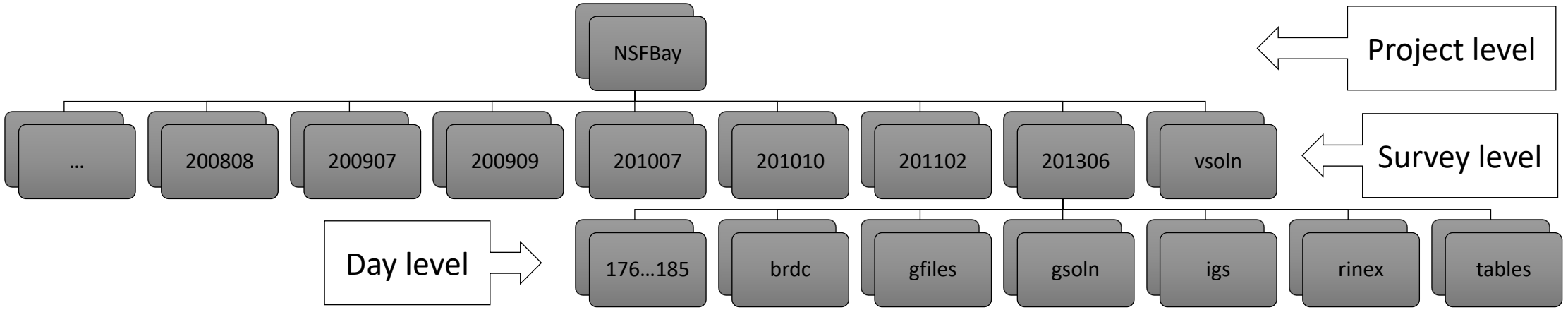
Processing directory

- The processing directory will not have the same structure as the main installation directory
- Choose a different location, do not process in your main installation directory
- We will, however, be copying or linking to the main installation tables (via symbolic link or “shortcut” ~/gg/tables)

Example continuous GPS structure



Example survey GPS structure



Additional software

- Generic Mapping Tools (GMT) (https://www.generic-mapping-tools.org/)
  - Required for plotting scripts to work
  - Scripts in com/ use GMT 5+
  - Prepend com_preGMT5/ to $PATH if using GMT 4
    - These scripts are no longer updated, so switch to GMT 6 or GMT 5!
- Tom's GGMatlab tools (http://geoweb.mit.edu/~tah/GGMatlab/)
  - tsview
  - velview