Using the CSIRO Mk3L climate system model
Part 1: Getting started

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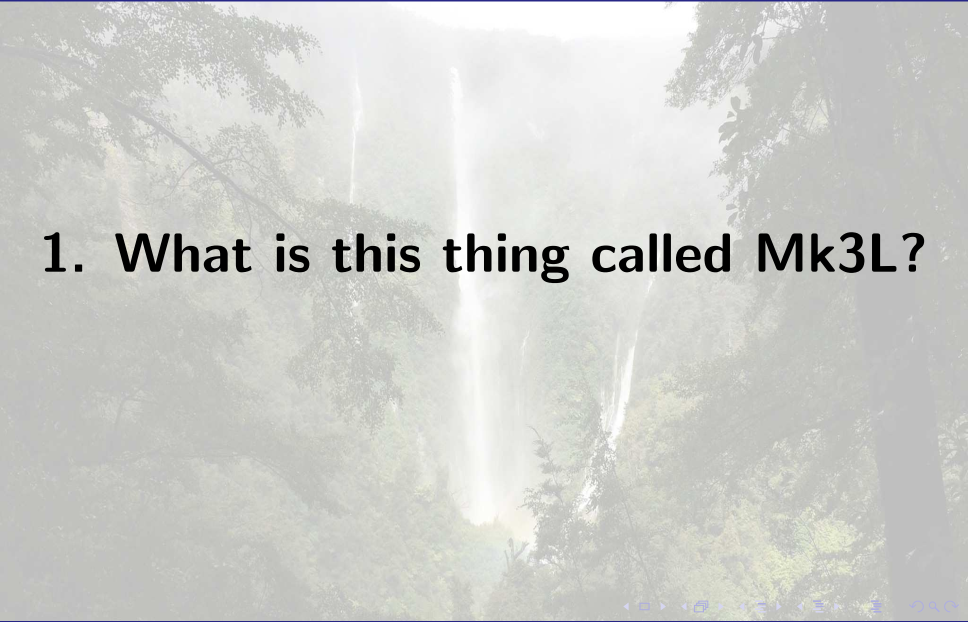
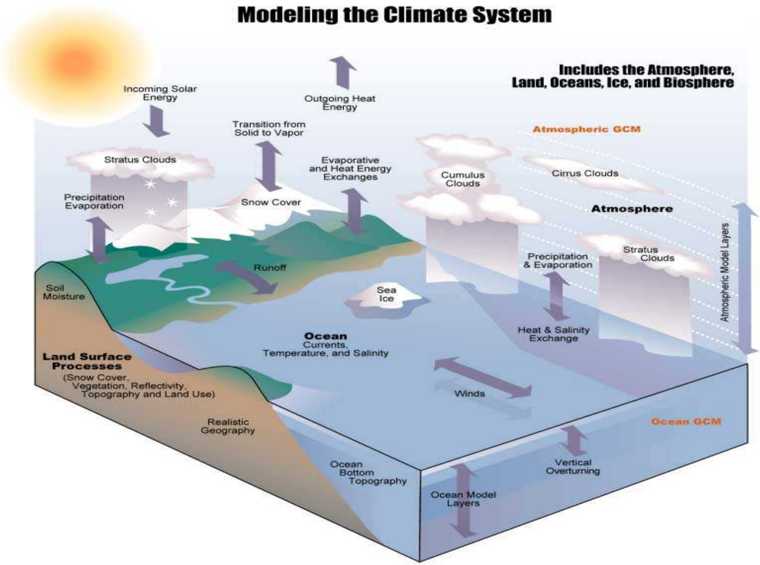
1. What is this thing called Mk3L?
2. What can it do?
3. Installing Mk3L
4. Running Mk3L
5. Output files



1. What is this thing called Mk3L?

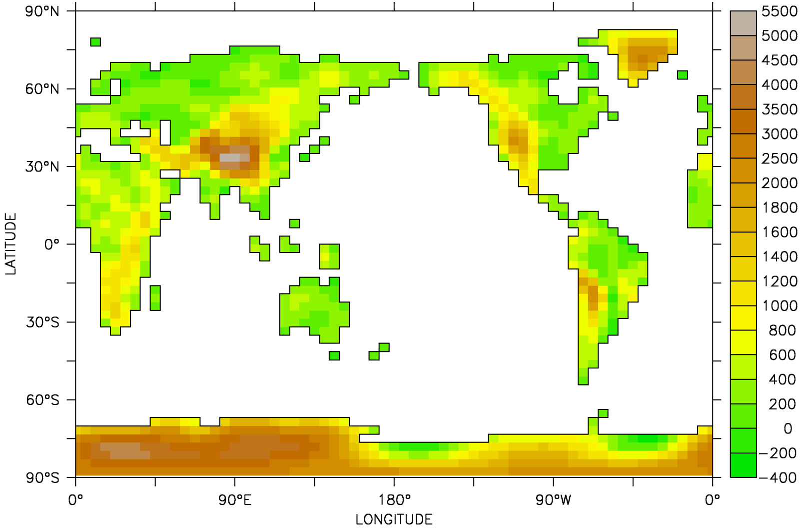
The CSIRO Mk3L climate system model

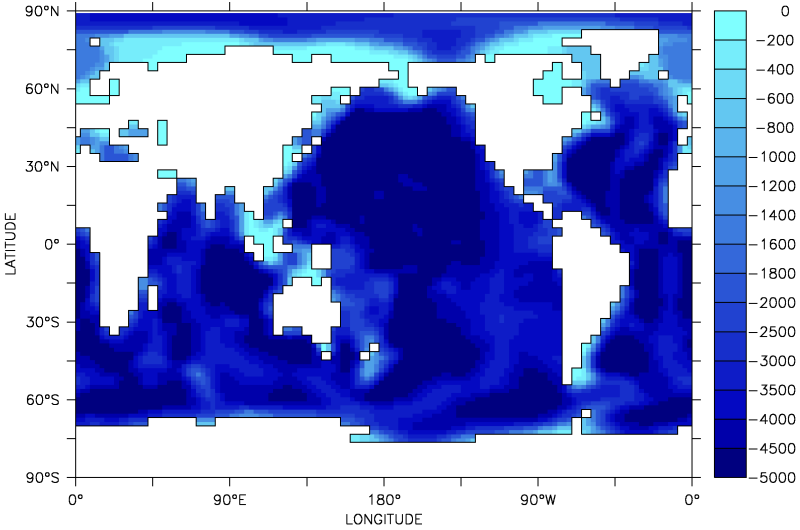
- Low-resolution version of the CSIRO climate system model
- Coupled atmosphere-land-sea ice-ocean general circulation model
- Designed to enable millennial-scale simulations of climate variability and change e.g.
    - palaeoclimate simulations
    - projections of future climate
    - low-frequency climate variability
    - process studies
- Can simulate 1000 years in around a month
- Community model

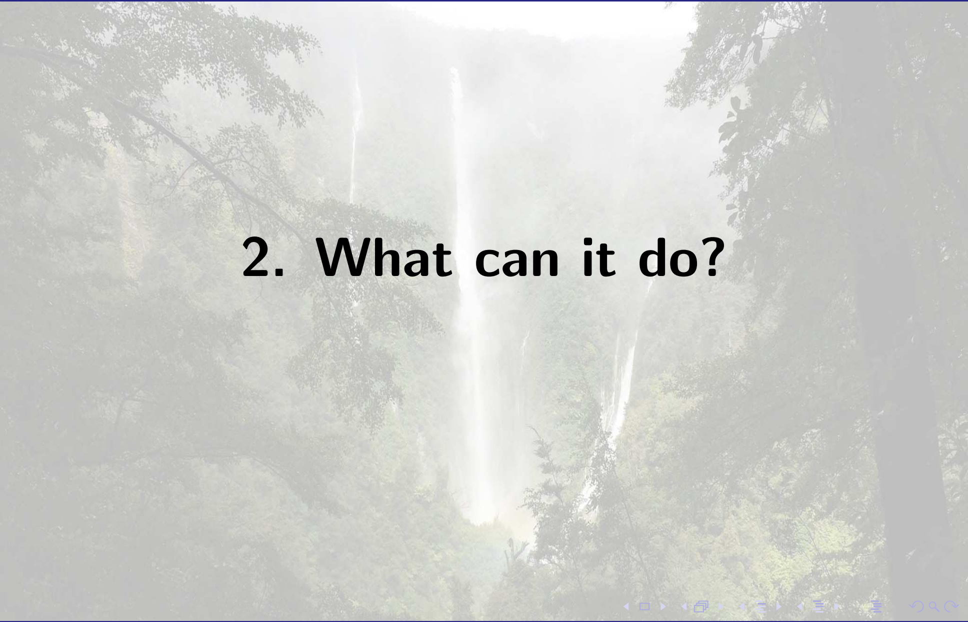

Modeling the Climate System
Includes the Atmosphere, Land, Oceans, Ice, and Biosphere
Incoming Solar Energy
Outgoing Heat Energy
Transition from Solid to Vapor
Stratus Clouds
Precipitation Evaporation
Evaporative and Heat Energy Exchanges
Snow Cover
Cumulus Clouds
Cirrus Clouds
Atmospheric GCM
Atmosphere
Stratus Clouds
Precipitation & Evaporation
Heat & Salinity Exchange
Atmospheric Model Layers
Runoff
Soil Moisture
Sea Ice
Ocean
Currents, Temperature, and Salinity
Land Surface Processes
(Snow Cover, Vegetation, Reflectivity, Topography and Land Use)
Winds
Realistic Geography
Ocean GCM
Ocean Bottom Topography
Vertical Overturning
Ocean Model Layers

The CSIRO Mk3L climate system model

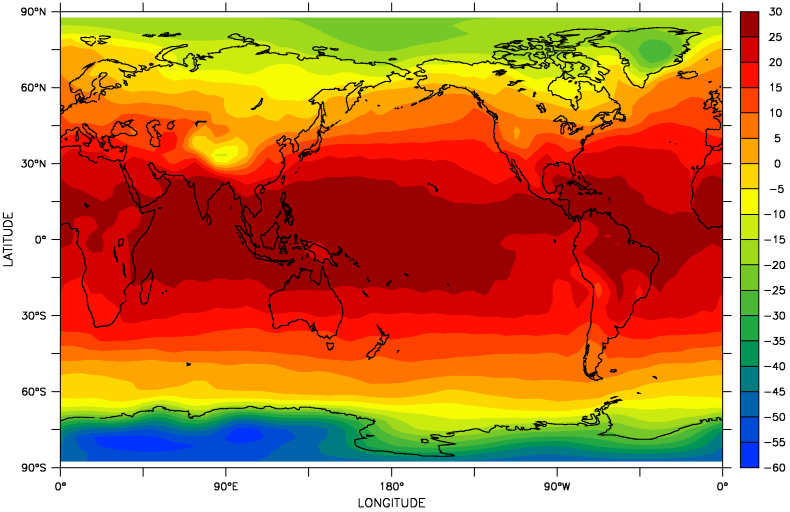
- Atmosphere:
  - Three-dimensional general circulation model
  - Horizontal resolution of $5.6^\circ \times 3.2^\circ$ with 18 vertical levels
- Ocean:
  - Three-dimensional general circulation model
  - Horizontal resolution of $2.8^\circ \times 1.6^\circ$ with 21 vertical levels
- Sea ice:
  - Dynamic-thermodynamic sea ice model
  - Three layers (two ice, one snow)
- Land surface:
  - Soil-canopy scheme (13 land surface/vegetation types, 9 soil types)
  - Six soil layers, three snow layers


90°N
60°N
30°N
0°
30°S
60°S
90°S
LATITUDE
0°
90°E
180°
90°W
0°
LONGITUDE
5500
5000
4500
4000
3500
3000
2500
2000
1800
1600
1400
1200
1000
800
600
400
200
0
−200
−400

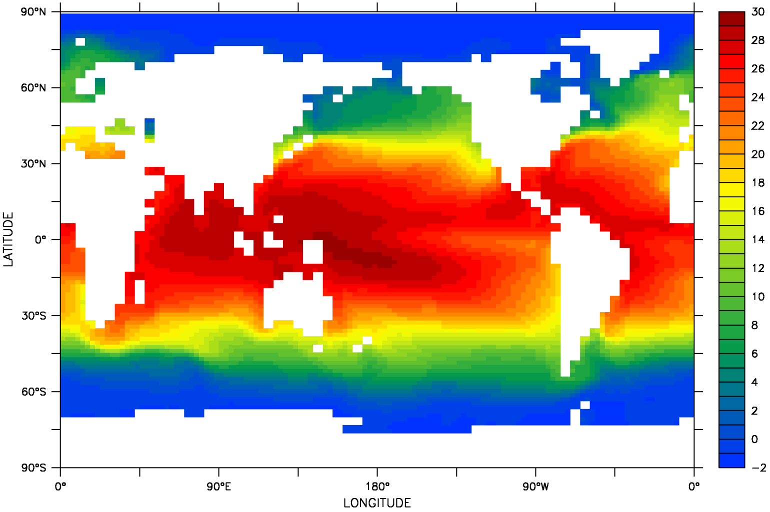

90°N
60°N
30°N
0°
30°S
60°S
90°S
LATITUDE
0°
90°E
180°
90°W
0°
LONGITUDE
0
−200
−400
−600
−800
−1000
−1200
−1400
−1600
−1800
−2000
−2500
−3000
−3500
−4000
−4500
−5000



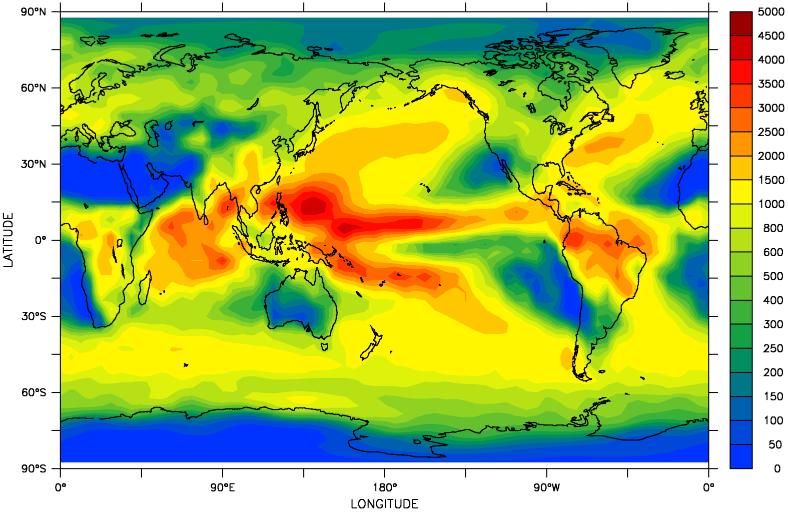
2. What can it do?



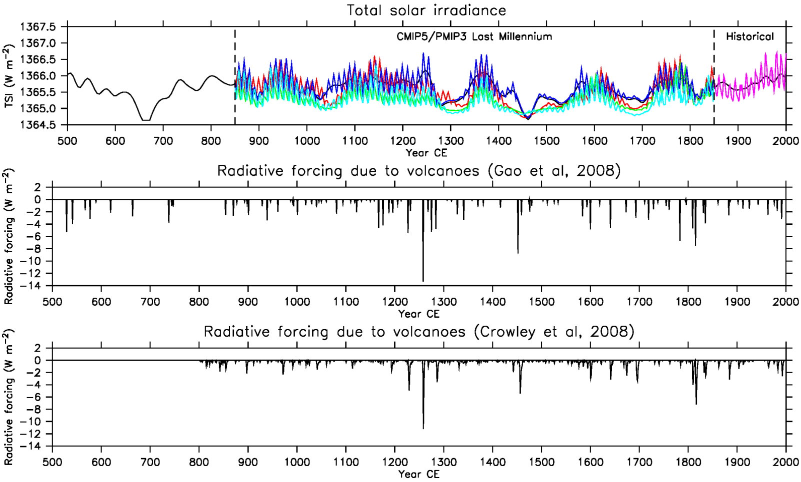
Simulated annual−mean surface air temperature (°C)

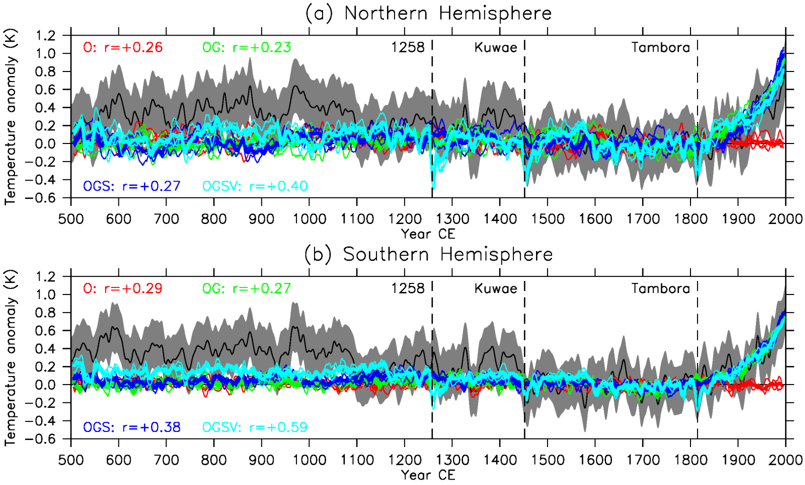


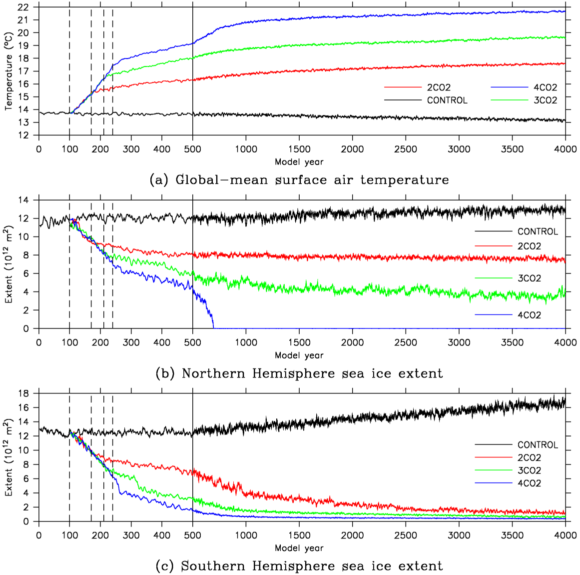
Simulated annual−mean sea surface temperature (°C)

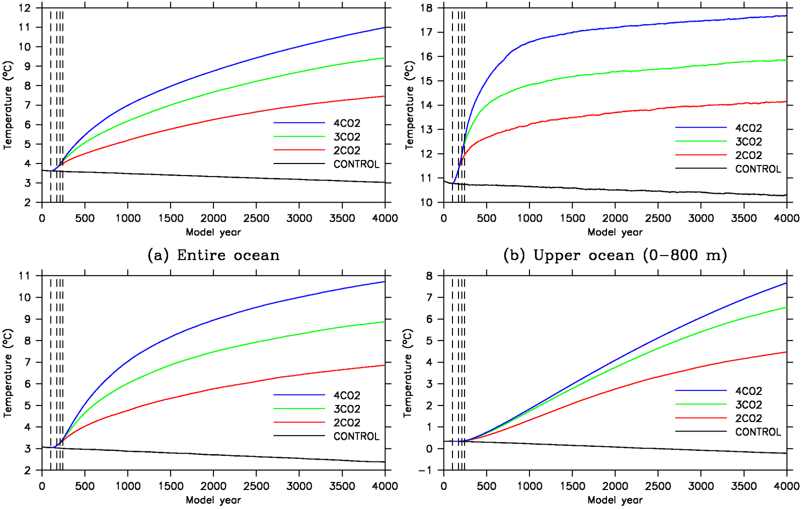


Simulated annual precipitation (mm)


Total solar irradiance
CMIP5/PMIP3 Last Millennium
Historical
TSI (W m^{-2})
Year CE
Radiative forcing due to volcanoes (Gao et al, 2008)
Radiative forcing (W m^{-2})
Year CE
Radiative forcing due to volcanoes (Crowley et al, 2008)
Radiative forcing (W m^{-2})
Year CE

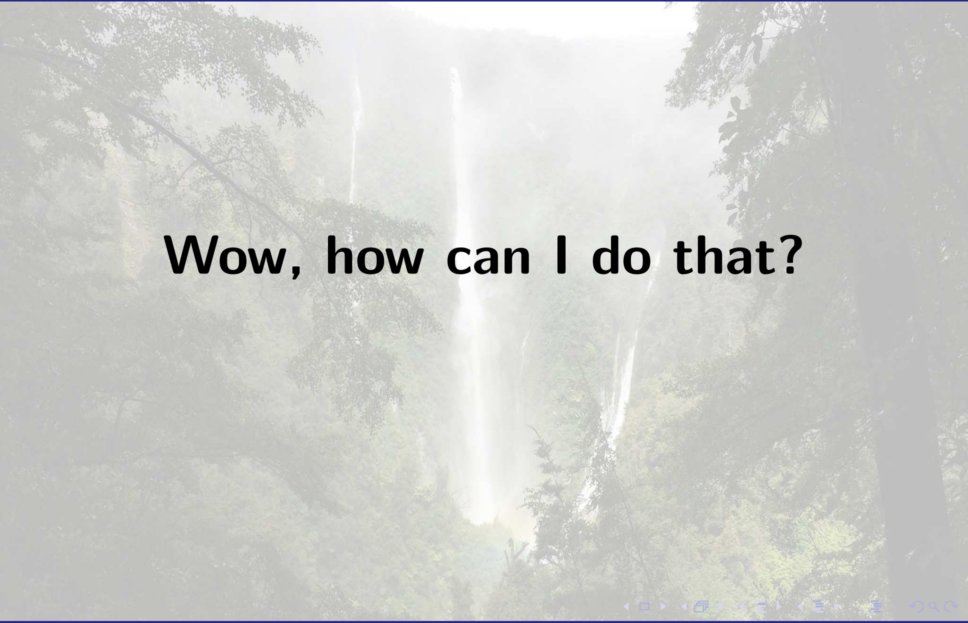

(a) Northern Hemisphere
O: r=+0.26
OG: r=+0.23
OGS: r=+0.27
OGSV: r=+0.40
1258
Kuwae
Tambora
Temperature anomaly (K)
Year CE
(b) Southern Hemisphere
O: r=+0.29
OG: r=+0.27
OGS: r=+0.38
OGSV: r=+0.59
1258
Kuwae
Tambora
Temperature anomaly (K)
Year CE


Temperature (°C)
Model year
2CO2
4CO2
CONTROL
3CO2
(a) Global−mean surface air temperature
Extent (10^{12} m^2)
Model year
CONTROL
2CO2
3CO2
4CO2
(b) Northern Hemisphere sea ice extent
Extent (10^{12} m^2)
Model year
CONTROL
2CO2
3CO2
4CO2
(c) Southern Hemisphere sea ice extent



(a) Entire ocean (b) Upper ocean (0–800 m)

(c) Mid–ocean (800–2350 m) (d) Deep ocean (2350–4600 m)



Wow, how can I do that?

3. Installing Mk3L

High-performance computing, 1969-style

Katana: A Faculty of Science computational cluster

- 133 x Dell blade compute nodes
- Total of 1,888 cores
- Linux operating system
- Portable Batch System (PBS) for running jobs
- Hostname is `katana.science.unsw.edu.au`
- For more information about Katana see:
  - `www.hpc.science.unsw.edu.au/cluster/katana`
- For more information about using the clusters see:
  - `www.hpc.science.unsw.edu.au/about/getting-started`

Exercise 1: Using Katana

- Launch Xming (Programs > Xming > Xming)
- Launch PuTTY (Programs > PuTTY > PuTTY)
- Using PuTTY, do the following:
  - Select Connection > SSH > X11
  - Check the Enable X11 forwarding box
  - Select Session
  - In the Host Name box, enter katana.science.unsw.edu.au
  - Click Open
  - Log in using your zNumber and zPass
- Familiarise yourself with the basic Linux commands (see the next slide)

Basic Linux commands

`ls`	list the contents of a directory
`ls -l`	create a long listing
`mkdir <directory>`	create the directory <directory>
`cd <directory>`	change to the directory <directory>
`cp <file1> <file2>`	copy the file <file1> to <file2>
`mv <file1> <file2>`	move the file <file1> to <file2>
`rm <file>`	delete the file <file>
`rmdir <directory>`	delete the directory <directory>
`man <command>`	display the manual page for <command>

- For some more Linux commands see:
  - www.dummies.com/how-to/content/linux-for-dummies-cheat-sheet.html

Subversion

- Subversion is a *version control system*
- Used to manage current and historical versions of files
- Operates via the internet, allowing a community of users and developers to seamlessly share a piece of software
- Mk3L is managed and distributed using subversion
- The Mk3L repository is located at the Tasmanian Partnership for Advanced Computing in Hobart (but could be anywhere)
- For further information see:
  - `http://subversion.apache.org` (includes free book!)

Exercise 2: Getting Mk3L

- We're not going to use subversion today. To save time, I've put a copy of the model distribution on Katana.
- Get Mk3L version 1.2 by entering the following commands:

```
cd
mkdir CSIRO_Mk3L
cd CSIRO_Mk3L
tar zxvf /srv/scratch/z3210932/mk3l-1.2.tar.gz
```

Exercise 2: Getting Mk3L

- The previous command created a new directory, `version-1.2/`
- Explore the contents of this directory – this is what a climate model looks like!

`core/`	Source code, data files and scripts needed to run Mk3L
`data/`	Useful datasets
`doc/`	Documentation
`post/`	Utilities for the analysis of model output
`pre/`	Utilities for the generation of restart and auxiliary files

Exercise 3: Compiling Mk3L

- Before you can run Mk3L, you need to *compile* and *test* it
- Compile the model by entering the following commands:

```
cd ~/CSIRO_Mk3L/version-1.2/core/scripts/
./compile
```

- Test the model by entering any of the following three commands:

`./test_atm`	Runs the atmosphere model for one day
`./test_cpl`	Runs the coupled model for one day
`./test_oce`	Runs the ocean model for one month

4. Running Mk3L

Running Mk3L

- The command which runs Mk3L is simply:

```
./model < input
```

- `model` is the *executable*. This is the "model".
- `input` is the *control file*. This contains the instructions which tell the model what to do.
- The above command *executes* the model and feeds it the information contained within the control file

Running Mk3L

- The model is usually run using the command:

```
./model < input > output
```

- This command takes the diagnostic information generated by the model, and *redirects* it to an output file
- For short jobs, the model can be run interactively
- However, for production purposes we need to use a *queueing system*
- Katana uses the Portable Batch System (PBS)

Exercise 4: Running Mk3L

- Run the model by entering any of the following three commands:

`qsub qsub_test_atm`	Runs the atmosphere model for one day
`qsub qsub_test_cpl`	Runs the coupled model for one day
`qsub qsub_test_oce`	Runs the ocean model for one month

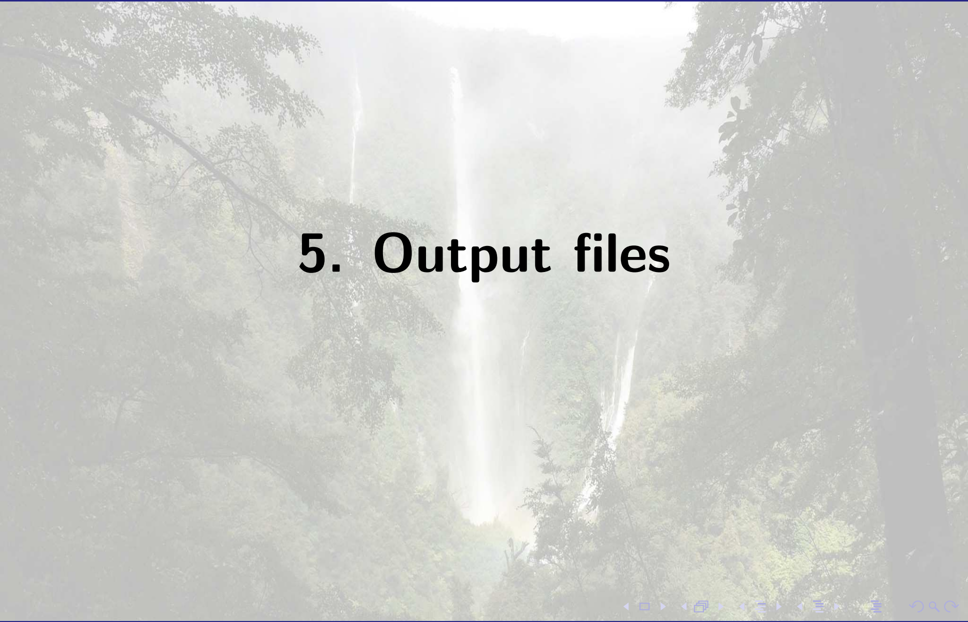
- The `qsub` command submits a job to the queueing system
- Use the command `qstat` to check the progress of your jobs
- Using the `less` command, examine each of the above scripts
- What do they do? The lines beginning with `#PBS -l` tell the queueing system which resources are required to run the job.

Requesting resources

- When using a queueing system, you need to request sufficient resources to run your job
- The scripts that you just ran use three different options to do this:

`nodes`	The number of nodes to run on
`vmem`	The total amount of memory required
`walltime`	The expected run time

- It's important to request sufficient resources, but not *too* much
- For further information see:
  - `www.hpc.science.unsw.edu.au/about/resource-requirements`



5. Output files

Output files

- The model generates two types of output:

output files	save the state of the model *during* a simulation
restart file(s)	save(s) the state of the model at the *end* of a simulation

- The output files contain the simulated climate
- See Chapter 6 of the Users Guide for further information

Exercise 5: Model output

- Get the course material for today:

```
cd
tar zxvf /srv/scratch/z3210932/week1.tar.gz
```

- These commands create a new directory, `week1/`, which contains some typical output from a coupled model simulation
- Use the Linux command `ls` to examine the contents of this directory
- You will see that the names of the files end with `.nc`
- These are netCDF files

What is netCDF?

- network Common Data Form
- A self-describing, machine-independent data format
- Probably the most common data format in the climate sciences
- The names of netCDF files usually end with `.nc`
- The command `ncdump` can be used to examine the contents of netCDF files
- For further information see:
  - `http://www.unidata.ucar.edu/software/netcdf/`

Exercise 6: netCDF

- Load netCDF by entering the command:

```
module load netcdf
```

- Use `ncdump` to examine the contents of the sample atmosphere model output file, `stsc_spi62.nc`. Try commands such as:

```
ncdump -h stsc_spi62.nc
ncdump -c stsc_spi62.nc
ncdump stsc_spi62.nc | less
```

- What can you see?

Ferret

- A free visualisation and analysis package
- Specifically designed for visualising climatic data
- Makes it a breeze to visualise, analyse and manipulate the contents of netCDF files
- Very powerful and easy-to-use averaging, interpolation and re-gridding capabilities
- Your new best friend!
- For further information see:
  - `http://ferret.pmel.noaa.gov/Ferret/`

Basic Ferret commands

`use <file>`	Load the netCDF file `<file>`
`show data`	List the data which is available
`list <variable>`	List the values of `<variable>`
`plot <variable>`	Produce a line plot of `<variable>`
`shade <variable>`	Produce a shade plot of `<variable>`
`fill <variable>`	Produce a filled plot of `<variable>`
`contour <variable>`	Produce a contour plot of `<variable>`
`exit` or `q`	Exit

Basic Ferret transformations

- If the variable `tsc` contains surface air temperature as a function of longitude and latitude, then these expressions have the following meanings:

`tsc[i=10,j=8]`	Temperature at gridpoint (10, 8)
`tsc[x=140e,y=35s]`	Temperature at 140°E, 35°S
`tsc[x=90e:180e,y=45s:0]`	Temperature within 90–180°E, 45-0°S
`tsc[i=@ave]`	Zonal-mean temperature
`tsc[i=@ave,j=@ave]`	Global-mean temperature
`tsc[i=@max,j=@max]`	Global-maximum temperature
`tsc[i=@min,j=@min]`	Global-minimum temperature

Exercise 7: Ferret

- Load and run Ferret:

```
module load ferret
ferret
```

- Within Ferret, load the sample atmosphere model output:

```
yes? use stsc_spi62.nc
```

Exercise 7: Ferret

- Try commands such as:

```
show data
fill tsc[k=1,l=1]
fill tsc[k=@ave,l=@ave]
fill tsc[i=@ave,k=@ave]
fill tsc[k=@max,l=@max]
plot tsc[i=@ave,j=@ave,k=@ave]
plot tsc[i=@ave,k=@ave,l=@ave]
plot tsc[x=140e,y=35s,l=@ave]
list tsc[i=@ave,j=@ave,k=@ave,l=@ave]
show transform
```

Exercise 8: Ocean model output

- A sample ocean model output file, `com.spi62.00001.nc`, is also provided
- Examine the contents of this file using `ncdump` and Ferret
- Within Ferret, try commands such as:

```
shade/lev=1d temp[k=1,l=1]
fill/lev=1d temp[i=@ave,l=@ave]
fill/lev=2dc motg[l=@ave]
plot mota[y=30n:60n@max,k=@max]
```

- Table 6.1 of the Users Guide will be useful here