Modelling using CSIRO Mk3L
Part 1: Getting started

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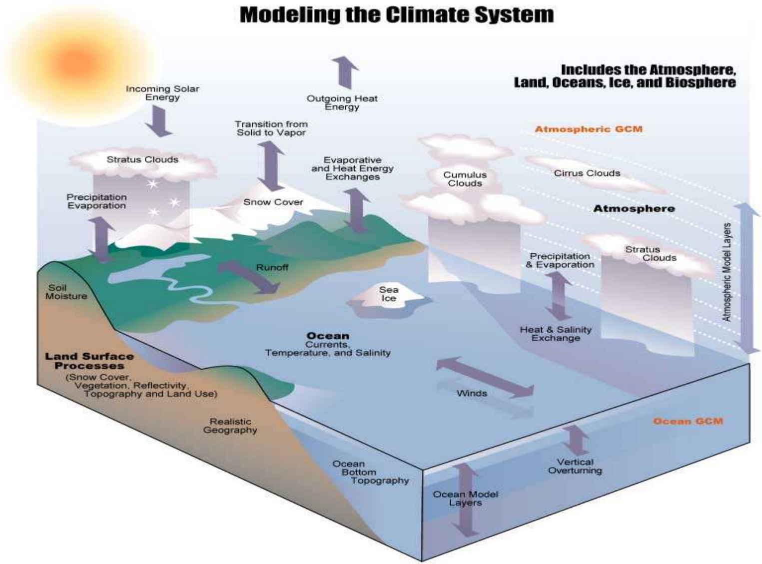
1. What is CSIRO Mk3L?


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

Choosing the right model for you

- A model is a *tool* – the type that you use depends upon the question that you want to answer.
- Which components of the climate system do you need to model?
- Which processes do you need to model?
- Which quantities do you need to model?
- Do you need a regional or a global model?
- How much spatial resolution do you need?
- How long do you need to run the model for?
- These questions are inter-related – for example, it isn't feasible to run a high-resolution global model for 10,000 years!
- *No* model is a perfect representation of the real world.

Different types of models

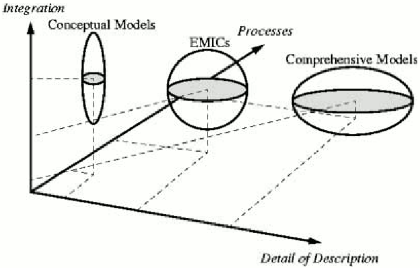


Fig. 1. Pictorial definition of EMICs. Adapted from Claussen (2000)

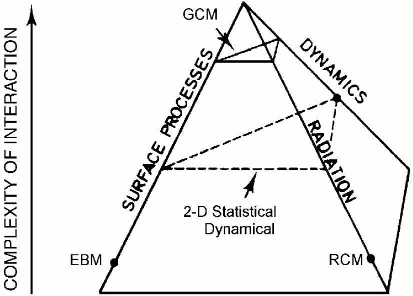
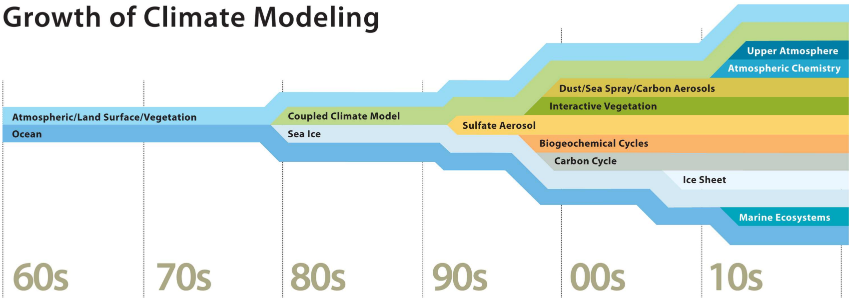


Fig. 2. The climate modeling pyramid. Adapted from Henderson-Sellers and McGuffie (1987)

Claussen et al. (2002), *Climate Dynamics*

The development of climate system models

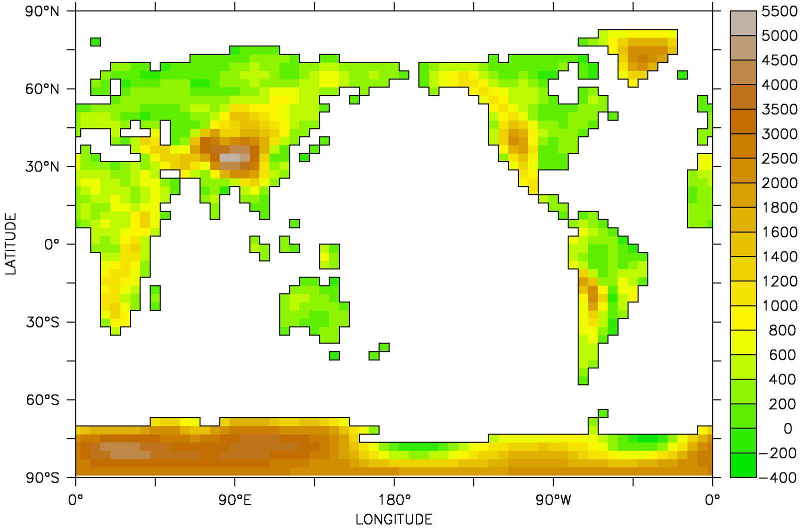


The CSIRO Mk3L climate system model

- Low-resolution version of the CSIRO climate system model (e.g. IPCC 1st, 2nd, 3rd, 4th and 5th Assessment Reports)
- 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

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
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60°S
90°S
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180°
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LONGITUDE
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600
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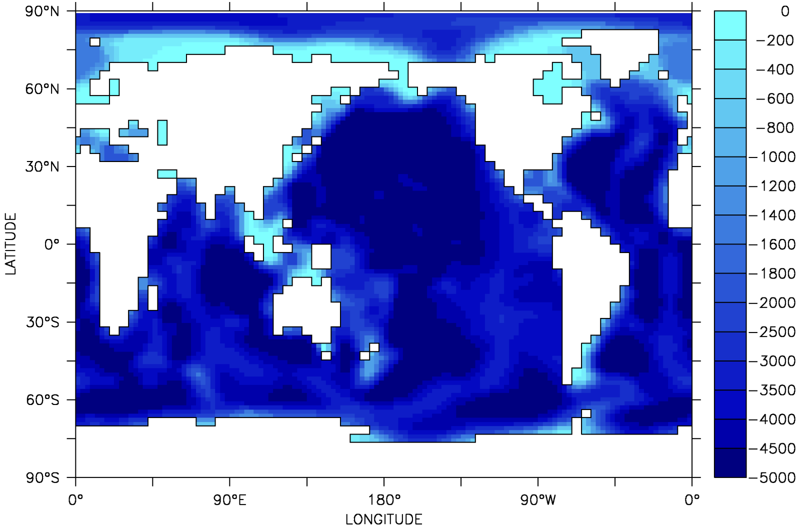
−200
−400


90°N
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LONGITUDE
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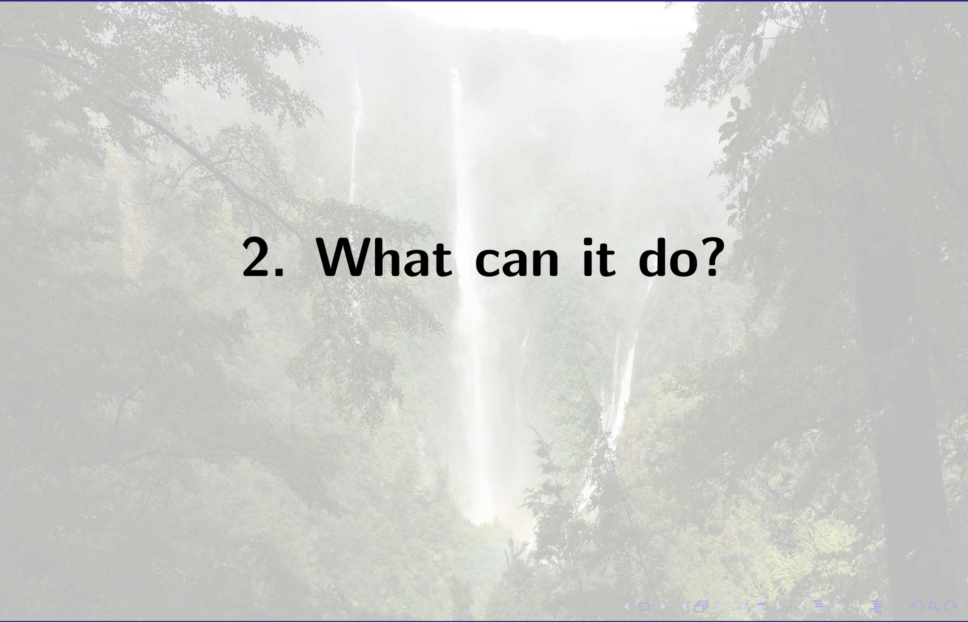
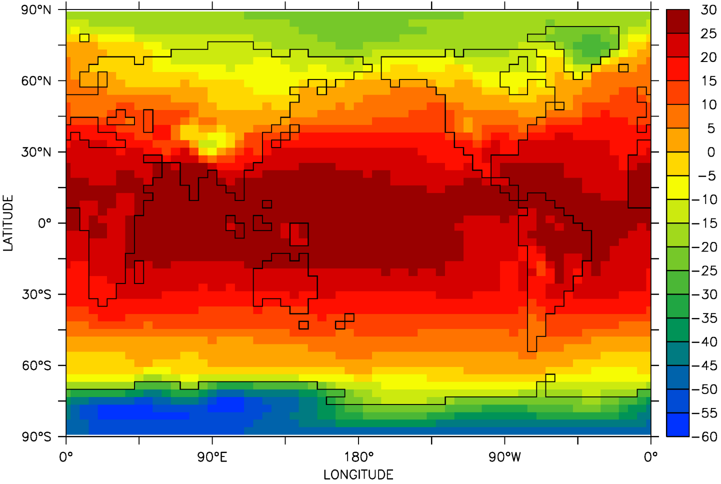
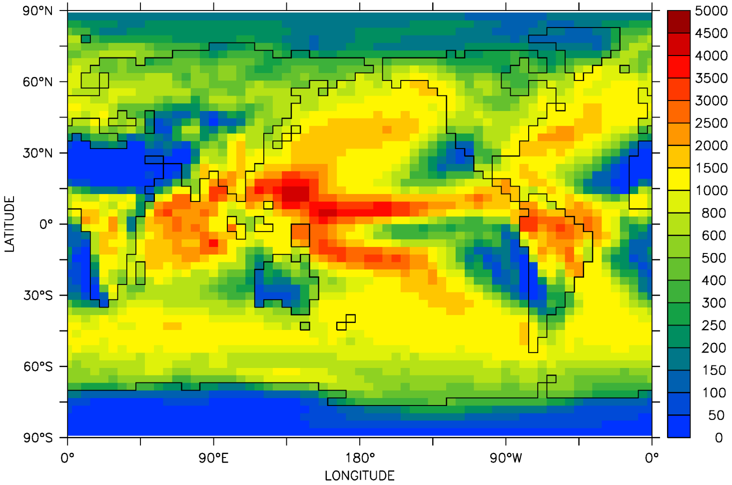


2. What can it do?

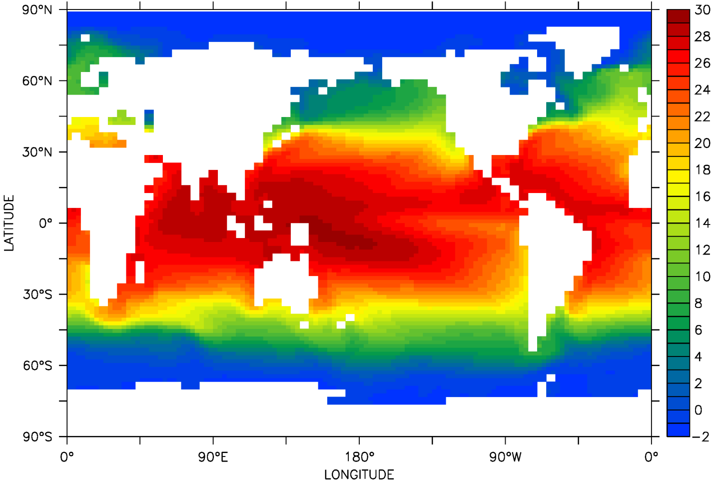
Simulated annual-mean surface air temperature (°C)



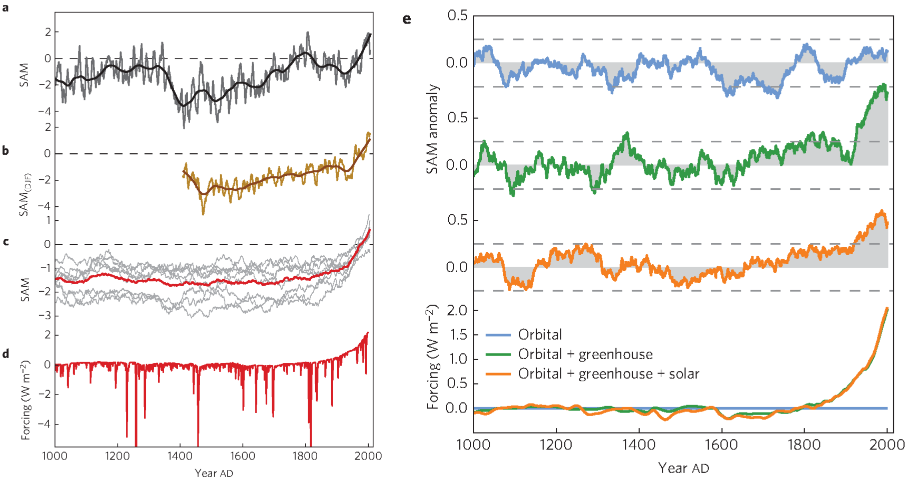
Simulated annual precipitation (mm)



Simulated annual-mean sea surface temperature (°C)

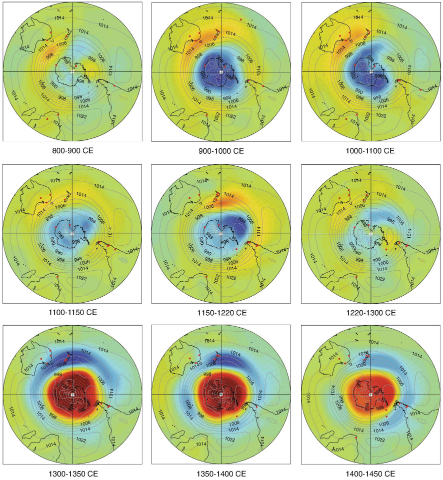


The evolution of SAM over the last millennium



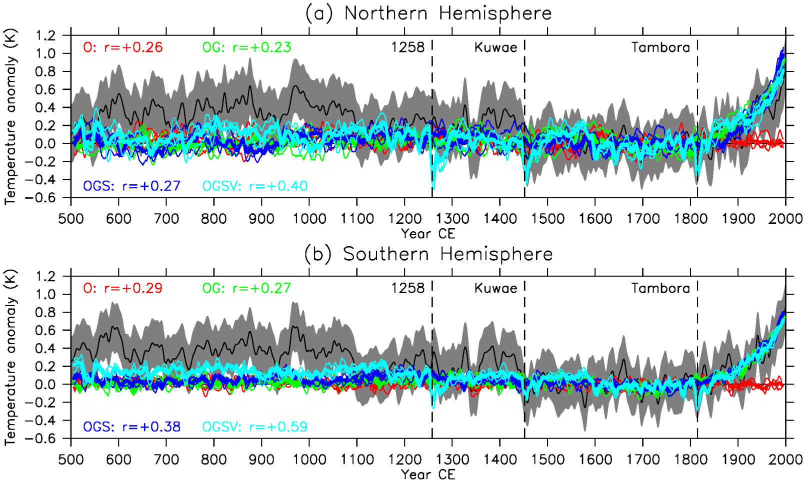
Abram et al. (2014), *Nature Climate Change*

Reconstructing MSLP anomalies using data assimilation



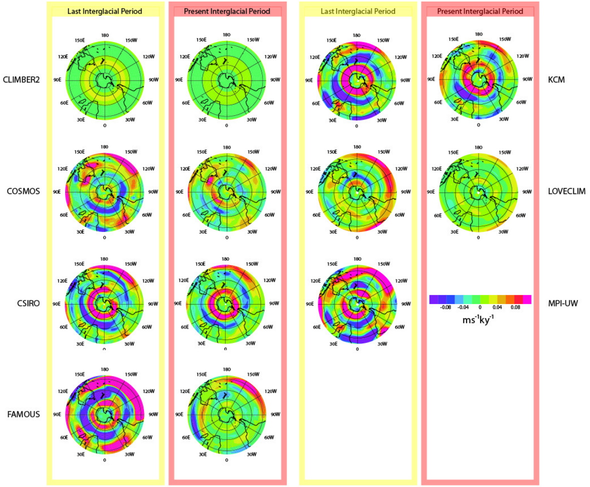
Goodwin et al. (2014), *Climate Dynamics*

The role of climate forcings over the past 1500 years



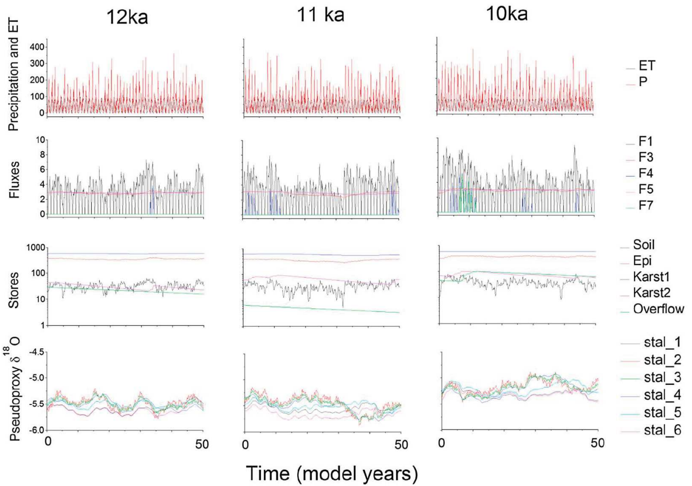
Phipps et al. (2013), *Journal of Climate*

The trend in zonal wind speed during interglacials



Bakker et al. (2014), *Quaternary Science Reviews*

Driving a forward model of stalagmite δ^{18}O



Baker et al. (2013), *Geophysical Research Letters*

3. Installing CSIRO Mk3L

The first coupled atmosphere–ocean GCM

786 JOURNAL OF THE ATMOSPHERIC SCIENCES VOLUME 26

Climate Calculations with a Combined Ocean-Atmosphere Model

SYUKURO MANABE AND KIRK BRYAN

Geophysical Fluid Dynamics Laboratory, ESSA, Princeton University, Princeton, N. J.

13 March 1969 and 6 May 1969

Empirical evidence indicates that the poleward heat transport by ocean currents is of the same order of magnitude as the poleward transport of energy in the atmosphere (Sverdrup, 1957). A significant contribution to the heat exchange across latitude circles is also associated with polar pack ice. Thus, any serious attempt to calculate climate must take into account the entire fluid envelope of the earth, consisting of the atmosphere and the hydrosphere. Although the cryosphere, consisting of ice packs over the oceans and continental ice, is not a fluid in the usual sense, it must be included in a general climatic model because of its large reflectivity to the solar insolation and its ability to store and transport heat.

taken into consideration. Velocity, temperature, water vapor and surface pressure are calculated at each of the grid points which are spaced approximately 500 km apart. Calculations are carried out at 9 levels which are chosen so that they resolve the structure of the lower stratosphere and the Eckman boundary layer. The radiation model is essentially that described by Manabe and Strickler (1964). For the sake of simplicity, the seasonal and diurnal variation of solar insolation are not taken into consideration; instead, annual mean insolation is assumed for this study. The depletion of solar radiation and the transfer of terrestial radiation is computed taking into consideration cloud and gaseous absorbers such as water vapor, carbon dioxide and

The first coupled atmosphere–ocean GCM

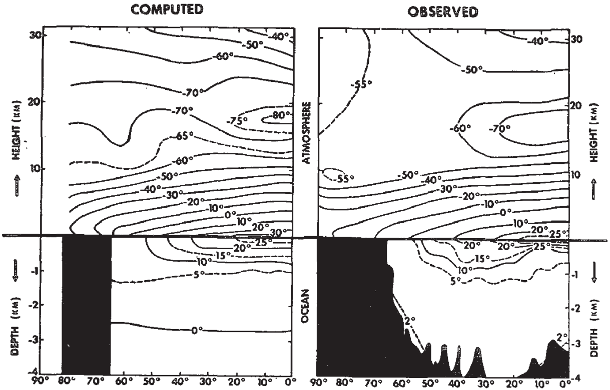


FIG. 2. Zonal mean temperature of the joint ocean-atmosphere system, left-hand side. This distribution, which is the average of two hemispheres, represents the time mean over two-sevenths of the period of the final stage of the time integration. The right-hand side shows the observed distribution in the Northern Hemisphere. The atmospheric part represents the zonally averaged, annual mean temperature. The oceanic part is based on a cross section for the western North Atlantic from Sverdrup *et al.* (1942).

Manabe and Bryan (1969), *Journal of the Atmospheric Sciences*

High-performance computing, 1969-style

High-performance computing, 1969-style

Katana: A computational cluster

- Owned and used by UNSW Faculty of Science
- 140 compute nodes
- Total of 2,000 Intel CPU 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`

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

Create your own workspace

- Most of you are going to be sharing a user account.
- It's important that you create your own workspace on Katana, so that you can keep your work separate from everyone else's.
- To do this, create your own directory. I suggest that you simply use your own name for this e.g. if your name is Jane, then call your directory `jane`.
- To create your directory, enter commands such as:

```
cd
mkdir jane
```

- In the following slides, replace `<NAME>` with the name of this directory.

Exercise 2: Getting CSIRO Mk3L

- First, you need to get your own copy of the model.
- Normally, you would download the model from a repository.
- However, to save time today, I've put a copy of the model distribution on Katana.
- Get version 1.2 of CSIRO Mk3L by entering these commands:

```
cd ~/<NAME>
tar zxvf /srv/scratch/z3210932/mk3l-1.2.tar.gz
```

- You'll see a lot of text scroll by as each file is extracted.

Compiling CSIRO Mk3L

- Before you can run CSIRO Mk3L, you need to *compile* it.
- This turns the source code into a program that you can run.
- Compile the model by entering these commands:

```
cd ~/<NAME>/version-1.2/core/scripts/
./compile
```

- Compilation will take around two minutes.
- You will see text scroll by as each source file is compiled.

Testing CSIRO Mk3L

- Before you can run CSIRO Mk3L, you should also *test* it.
- You can do this by entering this command:

```
./test_cpl
```

- This runs the full climate system model for one day. (It is possible to run the model in other modes, such as atmosphere only or ocean only, but we're not going to cover those in this course.)
- The test will take around 20 seconds to run.
- The model will display diagnostic text as it runs.
- If the text is successful, then the final line of text will be:

```
Stopped after   1 days.
```

4. Running CSIRO Mk3L

Running CSIRO Mk3L

- The basic command that runs CSIRO 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.
- You've already seen what happens when you do this: a lot of diagnostic information is written to the command line.

Running CSIRO Mk3L

- The model is usually run using this command instead:

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

- This takes the diagnostic information generated by the model, and *redirects* it to a file called `output`.
- For short jobs, the model can be run interactively.
- However, production jobs can take weeks or months to complete.
- We therefore need to use a *queueing system*.
- Katana uses the Portable Batch System (PBS).

Exercise 3: Running CSIRO Mk3L

- Run the model by entering this command:

```
qsub qsub_test_cpl
```

- This runs the model for one day.
- The `qsub` command submits a job to the queueing system.
- The file `qsub_test_cpl` tells the queueing system what to do.
- Use the command `qstat` to check the progress of your job:

```
qstat
```

- Hint: `qstat` lists all the jobs running on the cluster!

Exercise 3: Running CSIRO Mk3L

- The file `qsub_test_cpl` is called a *script*. The instructions contained within this file describe how to run the model.
- Using the `less` command, examine the contents:

```
less qsub_test_cpl
```

- Hint: type `q` to exit `less`.
- What does the script do?
- The lines beginning with `#` are comments.
- 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 script that you just ran uses 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`