The CSIRO Mk3L climate system model:

Input, output and post-processing

Input files

- The model requires three types of input files:

a control file configures the model for a particular simulation

restart file(s) initialise(s) the model at the *start* of a simulation

auxiliary files provide the boundary conditions *during* a simulation

- The model may be configured for a particular scenario by changing *either* the control file *or* one or more of the auxiliary files

Boundary conditions: atmosphere model

- Bottom boundary conditions:
  - Sea surface temperatures
  - Ocean currents
  - Topography
  - Albedo
  - Vegetation and soil types
- Radiative boundary conditions:
  - CO_2 transmission coefficients
  - Ozone mixing ratios

Boundary conditions: ocean model

- Upper boundary conditions:
  - Sea surface temperatures
  - Sea surface salinities
  - Surface wind stresses
- Bottom boundary conditions:
  - Bathymetry

Boundary conditions: coupled model

- Bottom boundary conditions:
  - Topography
  - Bathymetry
  - Albedo
  - Vegetation and soil types
- Radiative boundary conditions:
  - CO_2 transmission coefficients
  - Ozone mixing ratios
- Flux adjustments

Output files

- The model generates three types of output files:
  - Diagnostic information is written to standard output
  - The atmosphere model writes monthly-mean output to netCDF files (one per model variable)
  - The ocean model writes monthly-mean output to the binary file `fort.40`

Exercise: diagnostic information

- Using the `less` command, look at the diagnostic information written by the model

What is netCDF?

- 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 netCDF files

See `http://www.unidata.ucar.edu/packages/netcdf/`

Exercise: atmosphere model output

- The output files generated by the atmosphere model have names of the form `svvv_xxx.nc`, where `vvv` is the variable name and `xxx` is the run name
- Load netCDF on the SGI Altix AC, using the command:

```
module load netcdf
```

- Use `ncdump -h` and `ncdump` to look at some of the sample atmosphere model output
- Look at the list of all the variables which can be saved (Section 4.2.4 of the User's Guide)

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!

See `http://ferret.wrc.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 `tsu` contains surface temperature as a function of longitude and latitude, then the following expressions have the following meanings:

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

Exercise: Ferret

- Load and run Ferret on the SGI Altix AC, using the commands:

```
module load fluent
module load ferret
ferret
```

- Load some sample model output into Ferret using the command:

```
yes? use stsu_d73.nc
```

Exercise: Ferret (continued)

- Try commands such as:

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

Ocean model output

- Output is written to a binary file, `fort.40`
- This needs to be converted to a more portable and user-friendly format
- Utilities are provided for the *post-processing* of ocean model output:

`convert_averages`	converts `fort.40` to a netCDF file
`overturning`	calculates overturning streamfunctions
`annual_averages`	calculates annual-mean ocean model fields
`annual_overturning`	calculates annual-mean streamfunctions

convert_averages

- To use `convert_averages`, use the command:

```
./convert_averages fort.40 <output_file>
```

- This generates a netCDF file, containing the following variables:

`itt`	Number of timesteps since model start
`dtts`	Tracer timestep duration
`relyr`	Number of years since model start
`kmt`	Bathymetry
`smfzon`	Zonal wind stress
`smfmer`	Meridional wind stress

`stfht`	Surface heat flux
`stfsal`	Surface salinity tendency
`temp`	Potential temperature
`sal`	Salinity
`u`	Zonal velocity
`v`	Meridional velocity
`w`	Vertical velocity
`uedd`	Eddy-induced zonal velocity
`vedd`	Eddy-induced meridional velocity
`wedd`	Eddy-induced vertical velocity
`res`	Barotropic streamfunction
`cdepthm`	Maximum depth of convection

Exercise: `convert_averages`

- Use `convert_averages` to convert the sample `fort.40` file to netCDF, using a command such as:

```
./convert_averages fort.40 ocean.nc
```

- Use Ferret to examine the contents of the netCDF file

overturning

- To use `overturning`, use the command:

```
./overturning <input_file> <output_file>
```

- This generates a file containing the following variables:

`mola,molp,moli,molg`	Large-scale streamfunctions
`moea,moep,moei,moep`	Eddy-induced streamfunctions
`mota,motp,moti,motp`	Total streamfunctions

- The suffixes `a`, `p`, `i` and `g` indicate the Atlantic, Pacific, Indian and World Oceans

- The annual-mean streamfunctions are also calculated (`molaann`, `molpann`, `moliann`, `molgann`...)

Exercise: `overturning`

- Use **`overturning`** to calculate the meridional overturning streamfunctions, using a command such as:

```
./overturning ocean.nc over.nc
```

- Remember that the data file **`bsnmask.nc`** must be present in the same directory as **`overturning`**

- Use Ferret to examine the contents of the netCDF file

- Try entering the commands:

```
fill motaann[y=35s:90n]
contour/over motaann[y=35s:90n]
```

Exercise: Annual-mean output

- Two sample output files are provided:

```
com.ann.d73.02551-02600.nc
over.ann.d73.02551-02600.nc
```

- These files were generated using the utilities `annual_averages` and `annual_overturning` respectively, and contain annual means generated from 50 years of model output

- Use Ferret to examine the contents of these files

- Try entering the commands:

```
use over.ann.d73.02551-02600.nc
plot mota[y=30n:60n@max,k=@max]
```