ACCESS SAG Meeting, 5 July 2006, Bureau, 10 AM

Attendance


Unable to attend: A. Lynch, M. England, J. Raison

Agenda

• Action items from previous meeting:
  ACCESS web page (Puri)
  Resource gaps (Puri)
  Note of diagnostics/validation (Puri)
  Conversion of work plans to a unified format (Hirst)

• Communications with Met Office (Puri)

• Planning Reports
  Coupling CABLE to UM (Wang)
  Ocean Modelling (Alves)
  Assessment of Chemistry models (Hurley)

• Issues/Developments:
  Universities – Status of Workshop
  CSIRO
  Bureau

• Progress/Current Status with ACCESS modules (note these reports might need to be shortened depending on the time taken up by the discussion on planning reports):
  Unified Model (Jakob)
  VAR (Steinle)
  Coupling AusCOM with UM (Hirst)
  Infrastructure (Dix)

• Any other issues

• Next meeting

Action items from previous meeting

ACCESS Web site

• Joanne Richmond (CMAR) has developed a template for the site;
• Puri has forwarded ACCESS material to populate the various sections;
• SAG will be asked for comments/suggestions once the necessary links have been developed.
Resource Gaps

- Puri has prepared a note on the short-term (0-6 months) resource gaps;
- These will be discussed with Mitchell and Smith.

Note of diagnostics/validation

- A note is being prepared by Puri and will be sent out to SAG members for comment.

Conversion of work plans to a common format

- Updated infrastructure plan has been converted to the common format;
- An introductory section in all plans will be included;
- Completed plans will be put up on the ACCESS web site.

Communication with Met Office

- Puri reported on further fruitful communications with Met Office scientists;
- A key issue in running the UM from local initial conditions is in the generation of the so-called ancillary files. Puri contacted Stuart Bell, Head of NWP section, to ask if the software to generate these files could be made available to ACCESS. The software has now been received, and has been successfully implemented and executed by Dix. This should now allow us to run the UM from local initial conditions;
- Puri had written to Stuart Bell to ask if we could access the daily Met Office global model initial conditions. The response was prompt and positive. Mike Naughton has already started downloading these initial conditions and has successfully run the global UM here. The next step is to run the limited area version after which daily runs for the global and regional domains will commence;
- The climate version of the UM has been received from the Met Office and has been successfully executed by Dix – an extended run of ~1 year is planned.

Planning Reports

Coupling CABLE to UM

Wang presented the report ‘Development of land surface model for ACCESS’ prepared by Wang and Law and is included as Attachment A. The report provides a pathway for implementing CABLE and LPJ. It is pointed out that two issues need to be addressed, namely (i) a number of processes are duplicated between CABLE and LPJ, and (ii) three integration time steps are used in LPJ for different processes that introduce complications in the coupling. A strategy to address these issues is proposed that splits LPJ into two modules, namely (i) one module calculates establishment, mortality at yearly time step (Vegetation Dynamics, LPJ-VD), (ii) a second module calculates phenology, litter fall, allocation, growth at daily time step (growth and death, LPJ-GD). When a process is duplicated between CABLE and LPJ, representation of that process in CABLE is used for ACCESS. A staged
implementation strategy is then proposed as follows: (i) couple current version of CABLE to UM and develop the offline model calibration platform; (ii) develop LPJ-GD and the global version of CASACNP, and test with offline CABLE, (iii) couple CABLE + LPJ-GD to UM; (iv) develop LPJ-VD, test offline and then couple with ACCESS.

In the ensuing discussion the following points were made –

- No timelines are indicated in the report; these are needed to ensure that they fit within timelines for key ACCESS projects. Wang indicated that coupling could be achieved by end of 2007. SAG was of the view that this would not meet the NWP requirements;
- There was a discussion on how to address the NWP requirements in a timely manner. One possible fall back was to use the Met Office land surface scheme till CABLE becomes available; however it was felt that since CABLE represents a distinguishing Australian feature within ACCESS, a preferable approach is to aim for a faster timeline for coupling CABLE to the UM (the 2007 timescale for LPJ does not pose a problem since LPJ is not required for NWP applications). SAG therefore tasked Jakob and Steinle to meet with Wang to develop a pathway for meeting NWP requirements;
- Hydrology, including implementation of river routing, soil moisture initialisation which is important for NWP, is not specifically addressed in the report. Alan Seed noted that (i) there was strong interest in the hydrology community in using forecasts and analyses of precipitation, evaporation and potential evaporation, particularly over catchment basin scales and that river routing is relevant in these applications. SAG stressed the importance of giving some priority to hydrology aspects of land surface modelling; to this end Francis Chiew and Alan Seed were requested to prepare a short note on hydrology requirements from ACCESS;
- On river routing, Chiew noted that ACCESS should adapt an existing scheme rather than develop one from scratch and that since UM already has a river routing scheme it would be best for ACCESS to start with this scheme. Once coupling of CABLE is achieved, work on improvement to the scheme could commence. SAG supported this proposal;
- Chiew noted that another future hydrology-related issue that ACCESS will need to address is human influences such as irrigation which in turn has an impact on soil moisture initialisation for NWP models;
- On the CASACNP model, SAG noted that concern has been expressed at the lack of consultation with groups outside ACCESS; SAG expressed the view that although the science behind the CASACNP model was not in question, it is important to start dialogue with these groups in order to explain the reasons for using this model and to take on board their concerns;
- SAG noted (as has also been noted in the resource gaps note prepared by Puri) that there were clear resource gaps in the land surface modelling and that these need to be addressed with some urgency.

Ocean Modelling
Alves presented a skeleton ocean plan covering ocean modelling and data assimilation for all applications currently of interest to Bureau and CSIRO. This highlighted the complexity of the task as several different models are used by both organisations. The work plan has been broken down into work packages and a sample work package layout was provided. The next phase was to start writing the plans for the key packages, at least the ones on the shortest timeline.

In the ensuing discussion the following action items emerged:

- Alves to provide some "mud diagrams" to show the relationship between the different systems;
- Alves to discuss the skeleton plan with Schiller, Hirst and Bindoff before involving other scientists to ensure that it is consistent with other plans and in particular the coupled modelling plans; the discussions should also attempt to identify core ACCESS work in ocean modelling;
- Alves to provide drafts of key packages by next meeting.

### Assessment of Chemistry models

Peter Hurley presented his report ‘ACCESS Air Chemistry: Options Discussion Paper’ which is included as Attachment B. The report includes an assessment of three Chemistry models, namely (i) the Model of Ozone And Related Tracers (MOZART) model, (ii) the UK Chemistry and Aerosols (UKCA) model, and (iii) the CTM currently used in the AAQFS. The assessment includes a summary of the main features of the models, suitability for ACCESS applications, possible options for ACCESS based on a comparison of the strengths and weaknesses of the models for these applications. The main points emerging from the ensuing discussion were:

- SAG was impressed by the thoroughness of the assessment and thanked Hurley for communicating with key people and for preparing the report;
- SAG agreed with Hurley’s conclusion that the UKCA provided the best option for ACCESS, based on (i) easier and more natural path for coupling to the UM, (ii) amount of time and resources required for implementation, and (iii) ability to satisfy ACCESS requirements;
- Given that the recommendation to use UKCA involves divergence from the recommendation in the Project Plan to use MOZART, Hurley was asked to prepare a concise summary of support for the recommendation to use UKCA. This would be conveyed to the Steering Committee by Puri;

### Issues / Developments

#### Universities – Status of University-ACCESS Workshop

- The Workshop will be held on 9 August and is being convened by England and Lynch;
- Invitations to attend will be extended to a wide group of University scientists following clear preference of SAG members;
- A tentative agenda provided by England is as follows:

  1:30 pm  Introduction to ACCESS and its sub-models (45 mins incl. Qns)
CSIRO

Mitchell noted that:

- Considerable effort has been devoted towards addressing CSIRO supercomputing issues so that they will satisfy upgrade plans being developed by HPCCC;
- At a previous SAG meeting concern was expressed at the problems for CSIRO scientists relating to restrictions imposed by the firewall to outside users; possible solutions are being actively looked at;
- There have been continuing discussions on resource issues that were noted by Puri at the previous SAG meeting; possible steps to address these will be discussed with Puri;
- The University paper tabled by England at the June SAG meeting had an APAC-related attachment that included references to CSIRO (and Bureau); it is important to recognise that these attachments should be seen as discussion documents only and not as agreed actions.

Progress/Current Status with ACCESS modules

These reports were deferred to the next SAG meeting in order to allow sufficient time for discussions on the planning reports on ‘Coupling CABLE to UM’, ‘Ocean Modelling’, ‘Assessment of Chemistry modles’.

Other Issues/Information

- Puri and Wang attended a national meeting 'The Australian Community Climate Earth System Simulator and Australian Terrestrial Carbon Cycle Research' held in Canberra on June 8 and 9 and made a presentation on ACCESS. The meeting was hosted by the ARC Network for Earth System Science, the GCP and CSIRO. A highly encouraging aspect of the meeting is the high level of support and enthusiasm for ACCESS. However this is accompanied by similarly high expectations of ACCESS.
- The Steering Committee has convened a meeting on 18 July; Puri will attend.
Next SAG meeting

10AM on 9 August at the Bureau
Development of land surface model for ACCESS

Yingping Wang and Rachel Law

Land surface model in an earth system model typically consists of four key components for simulating surface flux, biogeochemical cycles, vegetation dynamics, land use and disturbance, respectively. This document will discuss what those four components are and identify a staged pathway for developing the land surface model for ACCESS. This pathway is not just a simple coupling of pre-existing models since some processes are duplicated with different representation in two or more modules, and the time step for integration varies within and among four components.

This document was written after the discussion on LPJ with Dr Allan Spessa, Max Planck Institute, Institute of Biogeochemistry, Jena and the GCP workshop from 5 to 9th June, 2006 in Canberra.

Before discussing the four components, explanation of some terminology used through this document is explained as follows:

Carbon cycle model: a model that simulates the carbon cycle in the terrestrial biosphere, ocean and atmosphere.

Uncoupled carbon cycle model: When a carbon cycle model is implemented into a climate model or earth system model, the concentration of radiative active greenhouse gas concentration in the atmosphere is prescribed, and is independent of the simulated atmospheric CO2 concentrations by the carbon cycle model.

Coupled carbon cycle model: When a carbon cycle model is implemented into a climate model or earth system model, carbon uptake by terrestrial biosphere and ocean depends on the atmospheric CO2 concentration that is calculated from the carbon cycle model and atmospheric transport, the calculated atmospheric CO2 concentration also contributes to the predicted (only the CO2 concentration, other greenhouse gas concentrations or radiative forcing from non-Co2 greenhouse gases are prescribed) radiative forcing.

Plant functional type: A group of plant species that have similar key traits is considered to a plant functional type. Key traits can be selected differently for different applications. For studies of the interactions between climate and terrestrial biosphere, the key traits considered also vary from model to model, but usually include a set of optical, morphological and physiological parameters as required by the land surface model.

Interactive terrestrial biosphere model: An interactive terrestrial biosphere model describes the exchange of heat, water and carbon between the land biosphere and atmosphere, growth and death of plants and change in soil carbon pool sizes with time. However the spatial distribution of plant functional types is prescribed, and unaffected by the growth or death of plants.
**Dynamic vegetation model:** A model describes the change in plant functional types with time as a result of competition, disturbance or climate change.

**Surface flux module (CABLE)**
CABLE has been recommended as the surface flux module for ACCESS. It simulates absorption of radiation of two big leaves in the canopy in the visible, near infra red radiation and long wave radiation, canopy interception and throughfall of precipitation, photosynthesis, plant respiration, soil hydrology, soil respiration, the temperature and moisture profile of the soil, and snow above the soil. Permafrost as special type of soil is also included in CABLE. CABLE simulates carbon, water and heat exchange between the land surface and atmosphere at the same time step as the atmospheric dynamics component of ACCESS. CABLE currently uses prescribed vegetation, soil type and leaf area index. We propose maintaining this mode of operation for NWP use but including plant phenology and carbon allocation to for a fully interactive carbon cycle in terrestrial biosphere (see LPJ below).

**Biogeochemical cycle module (CASACNP)**
CABLE only includes a simple representation of biogeochemical cycle, typically, three carbon pools in plants (leaf, wood and root) and one or two pools (fast and slow) in the soil. We recommend CASACNP as the biogeochemical module for ACCESS. CASACNP is developed from a very successful global biogeochemical model, CASA by adding the biogeochemical cycles of N and P to C cycle. It is the only global biogeochemical model that simulates nitrogen fixation and phosphatase production, two very important processes for simulating CO2 response when N or P are limiting net primary production, and plant competition for light above ground and nutrients below. Time step for integration is daily. The single position version of the model has been validated using measurements in Hawaii, a global version of the model is being developed. LPJ is not suitable for modelling biogeochemical cycles because it does not include N and P.

**Phenology and Vegetation dynamics (LPJ)**
It has been recommended that LPJ will be implemented into ACCESS. Several major international earth system modelling groups are to implement LPJ and its variants in their earth system models. In LPJ, plants are classified into 10 different plant functional types (PFT). For each PFT, carbon and water fluxes are calculated daily. Soil respiration and soil hydrology are also calculated daily using a two-layered soil model. Soil carbon dynamics is calculated using a two-pool soil carbon model. Competition for light between different PFTs within a GCM grid cell is also considered. Establishment of a PFT in a grid cell is estimated based on their bioclimatic zone that is defined by the threshold of maximum and minimal temperature and soil moisture. A PFT is killed when their annual carbon balance is negative, new PFTs are established if the bioclimate becomes suitable. Note that current versions of LPJ are limited to ‘potential’ vegetation i.e. human changes to land-use are not considered. Phenology and litter fall dynamics are also calculated monthly. There is significant overlap between the processes modelled by CABLE and by LPJ (see Table 1).

**Land use and disturbance including fire**
It is not planned to include land use and disturbance in ACCESS, we probably use what has been implemented in HADGAM by the UK Metoffice. Land use has only been included in earth system model of intermediate complexity (EMIC), not fully earth system models, such as ACCESS.

However the participation of C4MIP by the Aspendale group will help us to assess the impact of land change over the last 100 years on the simulated climate.

Table 1. The following table lists major processes in each of those three modules, and their integration time steps. If a process is represented in multiple components, we shall adopt the component that simulates that process at shorter time step.

<table>
<thead>
<tr>
<th>Process</th>
<th>CABLE</th>
<th>CASACNP</th>
<th>LPJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation absorption</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<tr>
<td>Photosynthesis</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<tr>
<td>Transpiration</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<td>Sensible heat exchange</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<tr>
<td>Canopy turbulence</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<td>Canopy interception</td>
<td>15 to 30 minutes</td>
<td>daily</td>
<td></td>
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<tr>
<td>Plant respiration</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<tr>
<td>Soil respiration</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<tr>
<td>Soil hydrology</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<tr>
<td>Soil temperature</td>
<td>15 to 30 minutes</td>
<td>daily</td>
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<td>Soil moisture</td>
<td>15 to 30 minutes</td>
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<tr>
<td>Litter fall</td>
<td>daily</td>
<td>monthly</td>
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<tr>
<td>Phenology</td>
<td>daily</td>
<td>daily</td>
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<tr>
<td>Soil respiration</td>
<td>15 to 30 minutes</td>
<td>daily</td>
<td>daily</td>
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<tr>
<td>Nitrogen cycle</td>
<td>daily</td>
<td>daily</td>
<td></td>
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<td>Phosphorus cycle</td>
<td>daily</td>
<td>daily</td>
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<tr>
<td>Establishment</td>
<td>daily</td>
<td>yearly</td>
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<tr>
<td>Light competition</td>
<td>daily</td>
<td>daily</td>
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<tr>
<td>Mortality</td>
<td>yearly</td>
<td>yearly</td>
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<td>Nutrient competition</td>
<td>daily</td>
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<td>Allocation</td>
<td>daily</td>
<td>Yearly</td>
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<tr>
<td>Growth</td>
<td>daily</td>
<td>daily</td>
<td>Yearly</td>
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</tbody>
</table>

*Pathway for ACCESS*

Development of land surface model for ACCESS includes the development, implementation and parameterization. It is recommended that CABLE and LPJ will be implemented in ACCESS.

Two issues exist: several processes are duplicated between CABLE and LPJ and three integration time steps have been used in LPJ for different processes, and will make it difficult for parameterisation. To resolve these two issues, we recommend that LPJ is split into two modules: one module calculates establishment, mortality at yearly time step (Vegetation Dynamics (LPJ-VD)) and other module calculates phenology, litter fall, allocation, growth at daily time step (growth and death (LPJ-GD)). When a process is duplicated between CABLE and LPJ, representation of that process in CABLE is used for ACCESS.
Each module is integrated at a fixed time step. That would allow for parameterizing each module independently of other modules. The information exchange between different modules is shown in the following diagram.

**Parameterization**

Model-data assimilation is one of the most efficient tools for calibrating models using observations. We have calibrated CABLE using carbon fluxes from CASA model and atmospheric concentrations, and flux measurements from eddy covariance towers worldwide. We have also developed two techniques for model calibrations: Kalman filter and gradient method. A novel way of calculating tangent linear from FORTRAN 90 codes developed by Professor Ian Enting has made gradient method quite promising for estimating parameters of complex models, such as the individual modules in the land surface model for ACCESS.

To estimate all parameters in different modules of the land surface model for ACCESS, we need to develop a modelling platform that can be used to estimate the model parameters systematically in order to ensure the compatibility and consistency of model parameters for different modules. It is recommended that CCAM with CABLE will be used to generate meteorological forcings for the period 1900 to 2000 using the setup of C4MIP phase I experiments and all meteorological forcings required to run different modules will be saved at the finest time resolution possible. They are: incoming short-wave radiation, long-wave radiation, air temperature, humidity wind speed at the surface or lowest level, precipitation, surface CO2 concentration. These forcings will drive an offline version of CABLE, the output from offline version of CABLE includes, daily photosynthesis, plant respiration, soil temperature and moisture will drive both LPJ-GD and CASACNP offline. Output from LPJ-GD and CASACNP includes annual carbon fluxes from each PFT, and daily maximum and minimum temperature and soil moisture, which are used as input to LPJ-VD.

**Development stages**

Development of land surface model for ACCESS is guided by the requirement of IPCC AR5. That requirement is the inclusion of full carbon cycle (both terrestrial and oceanic carbon cycles) in ACCESS. Both CSIRO and BoM are committed to deliver results for IPCC AR5. However it is not clear whether vegetation dynamics or change in species composition is an essential requirement for IPCC AR5.

To implement a full carbon cycle into ACCESS, we recommend the development to be divided into four stages. Stage 4 is likely to be incomplete for IPCC AR5.

**Stage 1. Couple current version of CABLE to HADGAM, and develop the offline model calibration platform**

Some technical issues:
- Possible difficulty in taking MOSES (counterpart of CABLE in HAGGAM) from the atmospheric dynamics core codes.
- Incompatibility between MOSES and CABLE
• No generic best method for calibrating model components offline

Actions to be taken:
• One scientist from CSIRO will spend three months in the Hadley Centre and University of Bristol, another senior scientist will visit UK for one month in 2006/7.
• Employ an IT support person
• Take the phenology component out of LPJ, develop a calibration strategy and use it to calibrate the phenology model using 20 years AVHRR measurements of leaf area (1980-1999).
• Need to employ or allocate a person dedicated to developing the model calibration framework at global scale

*Stage 2. Develop LPJ-GD and the global version of CASACNP, and test with offline CABLE*

*Stage 3: Couple all to ACCESS*

*Stage 4: Create LPJ-VD, test offline and then couple with ACCESS*
CSIRO may be able to reallocate 0.5 EFT to work on compiling global dataset of biomass burnt over the last two decades. This dataset will be used to calibrate the disturbance module in HADGAM. Details of this work has yet to be workout out.
Figure 1. Linkage between the four components
ATTACHMENT B

ACCESS Air Chemistry: Options Discussion Paper

By Peter Hurley

June 2006

Background

The September 2005 Project Plan for ACCESS recommended the following:

Recommendation 1.1.4/1.2.5: ACCESS should initially import the MOZART Chemistry model in order to gain expertise with running the model in stand-alone mode and to eventually implement simplifications to enable it to run interactively, which was subsequently endorsed as a starting point by the ACCESS Steering Committee.

The February 2006 Scientific Advisory Group (SAG) meeting recommended:

• Initial emphasis will be on stratospheric ozone and environmental prediction (not IPCC)
• Task appropriate person to provide recommendations on how ACCESS can move forward in this area – note that the Project Plan recommended that we import MOZART in the first instance

and so subsequently 0.5 FTE was allocated from April 2006 to begin work on the Air Chemistry Task, initially to review and assess possible options for ACCESS air chemistry.

In discussion with members of the ACCESS SAG during April 2006, the scope of the above was widened to include an examination of the UK Chemistry and Aerosols (UKCA) model and to also consider urban scales (as well as global and regional scales) and so include the CTM currently used in AAQFS (currently run offline from meso-LAPS).

The following Sections will provide ACCESS Air Chemistry modelling options for discussion at the July 2006 SAG meeting.

Some Assumptions

The following has been assumed for this document:

• ACCESS will be using the atmospheric component of the UK Unified Model (UM) as the core atmospheric model
• ACCESS has access to MOZART V3&V4, UKCA and AAQFS CTM models
• ACCESS Air Chemistry is to be considered separately to ACCESS Aerosols
• The preferred approach to connecting new modules to the UM for ACCESS is to use a coupler (e.g. OASIS4)
• Support will be provided from appropriate ACCESS groups to help with connectivity to Air Chemistry module components, as needed
• Support will be available from the Model Infrastructure Team on using the UM and the coupler, and on version control, etc, as needed
• Extension of the AAQFS system to other cities (currently Sydney, Melbourne and Adelaide) would be undertaken (and funded) externally to ACCESS
• Cooperation, collaboration and support will be available from scientists at CSIRO and the Bureau on ACCESS Air Chemistry

Existing Models

Based on the Background and Assumptions Sections above, three Chemical Transport Models (CTMs) have been considered for ACCESS:
• MOZART (Model for OZone And Related Tracers Global) CTM
• AAQFS (Australian Air Quality Forecasting System) CTM
• UKCA (United Kingdom Chemistry and Aerosols) CTM

Note that the UKCA is already connected directly to the UM without the use of a coupler. Other CTMs could have been considered, but the above models were considered to encompass the broad range of models available, and also have either a past, present or future connection to the organizations involved in ACCESS.

The following is a brief summary of the main features of the next version of each model:

**MOZART V4:**
- Likely to be available Q3 2006 as a Community Model, supported by NCAR
- Pre-processor (chemical compiler) available to enable code generation for new species/schemes
- Emissions provided with the model
- A biogenic emissions scheme
- Global (non-nestable) Model in offline MATCH framework for advection, diffusion, convection, deposition, etc
- Comprehensive Tropospheric Chemistry (gas-phase and heterogeneous, with ~80 Species including NOx, N2O and speciated VOCs, Ozone, Methane, Sulfur Cycle, NH3)
- A comprehensive aerosol scheme (e.g. several Primary Emission Species, SOA, nitrates, sulphates, etc), linked into chemistry scheme (not yet clear how many prognostic variables, but likely ~20 to 30)
- A (relatively) fast and interactive Tropospheric radiation scheme (FTUV) for species reaction rates with gas/aerosol feedback
- Good Modular F90 code with Vectorisation and OPENMP/MPI included
- Well verified model for global offline applications – several Journal publications available

**AAQFS CTM V2:**
- Likely to be available Q3 2006 as Australian (CSIRO+BoM+EPA) Community Model, supported by CSIRO
- Pre-processor (chemical compiler) available to enable code generation for new species/schemes
- A plume rise module for elevated point sources
- Urban Emissions provided with the model
- A biogenic emissions scheme with multi-layer canopy effects
- Urban (+likely Regional) nestable, multi-grid, Model inline/offline in it’s own framework for advection, diffusion, convection, deposition, etc (configuration’s for offline LAPS and inline/offline TAPM currently available)
- Comprehensive Tropospheric Chemistry (gas-phase, with 50 Species (US EPA CB05 Mechanism + Several Others) including NOx and speciated VOCs, Ozone, Methane, Sulfur Cycle, NH3)
- Moderately comprehensive aerosol scheme (e.g. several Primary Emission Species, SOA, nitrates, sulphates, etc), linked into chemistry scheme
- Look-up tables for species reaction rates without gas/aerosol feedback
- Good Modular F90 code with Vectorisation and OPENMP included (PC-Window/Linux, SGI, NEC SX6)
- Well verified model for urban applications – several Journal publications and Reports available
Also used by CSIRO & Australian EPAs for Regulatory Applications (TAPM-CTM in non-forecast mode)

**UKCA V1:**
- Likely to be available Q3 2007 as UK Community Model, supported by UKCA Consortium (incl. UKMO)
- Pre-processor (chemical compiler) available to enable code generation for new species/schemes
- Emissions provided with the model
- A biogenic emissions scheme
- Global (+likely Regional/Urban nestable) Model inline in UKMO UM framework for advection, diffusion, convection, deposition, etc
- Methane Chemistry Mode (12 Species (subset of Tropospheric Mode below))
- Moderately Comprehensive Tropospheric Chemistry (gas-phase, with 24 Species (+14 in Extended Mode, +9 in Aerosol Mode) including NOx and speciated VOCs, Ozone, Methane, Sulfur Cycle, NH3)
- Moderately Comprehensive Stratospheric Chemistry (gas-phase and heterogeneous, with 15 Species (+7 in Extended Mode) including NOx and N2O, Ozone, Methane, Sulfur Cycle, CLOx, BrOx, CFC’s)
- Moderately comprehensive aerosol scheme (e.g. several Primary Emission Species, SOA, nitrates, sulphates, etc), linked into chemistry scheme
- Choice of look-up tables or a fast and interactive Tropospheric and Stratospheric radiation scheme (FAST-J) for species reaction rates with gas/aerosol feedback
- Likely to be good Modular F90 code with Vectorisation and OPENMP/MPI included
- Increasingly well verified model for global applications – too early yet for Journal publications, but there are some reports available (more to come)

Note that MOZART V4 is the latest version of the model for the troposphere. MOZART V3 is an unsupported version of the model that includes MOZART V2 tropospheric chemistry as well as a stratospheric chemistry scheme, and this version would need to be obtained for stratospheric applications.

Note also that MOZART and AAQFS CTM models are currently used offline, although AAQFS CTM is already configured to run inline in other models (e.g. TAPM-CTM – an urban and local scale meteorology and air pollution model), while the UKCA model is already inline in the UM.

**ACCESS Applications**

It is anticipated that ACCESS will provide a Unified Modelling framework for meteorological and air pollution model development, verification, and applications within the Bureau, CSIRO and potentially for the University Sector. The Air Chemistry component of ACCESS will thus potentially provide a CTM modelling framework and capability to these organizations.

In collaboration with CMAR, BMRC and the University Sector, the applications that are considered in-scope for ACCESS are:
- general CTM applications for Earth Systems Modelling (ESM)
- tropospheric and stratospheric Climate modelling
- tropospheric NWP

More specifically, these applications will include modelling at Global, Regional and Urban scales for:
- emissions inventory modelling and dataset compilation
- ESM and applications, especially those relevant to the Cape Grim Program
- NWP and forecasting, especially for operational/commercial applications
- ESM for Climate applications, especially those relevant to the IPCC Program and those that will feed-into Climate Impact Assessments

With each of the three models listed in the previous Section essentially in their current form; there is a clear first model choice for some applications as summarized in Table 1. In making the assessment presented in the Table, it was assumed that for NWP applications an offline model is sufficient, while for ESM applications an inline model is necessary in order to correctly simulate important climate feedback effects. Model run time was also considered to be as important as the complexity of the science in the model for ESM applications, but not necessarily for NWP (although operational time-windows may eventually be of some concern for NWP). Note that none of the models are currently in a form that, with little or no development work (assuming familiarity with running the model is already established), can immediately be run for Urban tropospheric/stratospheric ESM applications.

Table 1. Most suitable model for various Applications and Scales in (essentially) their currently available form.

<table>
<thead>
<tr>
<th>Application (Scale)</th>
<th>Global</th>
<th>Regional</th>
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</tr>
</thead>
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<tr>
<td>NWP (Troposphere)</td>
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</tr>
<tr>
<td>ESM (Troposphere)</td>
<td>UKCA</td>
<td>UKCA</td>
<td>-</td>
</tr>
<tr>
<td>ESM (Stratosphere)</td>
<td>UKCA</td>
<td>UKCA</td>
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</table>

Other applications not considered within the 5-year timeframe considered in this paper are:
- The Bureau operational Regional scale emergency response modelling capability (e.g. for nuclear accidents, volcanic eruptions, airborne disease, etc). These applications currently use the LAPS/HYSPLIT models, but with appropriate resources, these emergency response applications could eventually be performed using the ACCESS system
- The CSIRO CTM development, verification and consultancy work for Urban scale air pollution hind-casting and regulatory applications, which use TAPM-CTM (same CTM modules as the AAQFS CTM). It is envisaged that this capability will continue to be supported by CSIRO independently of ACCESS. However, it is recommended that collaboration between ACCESS and the CSIRO CTM for Urban applications should be encouraged wherever practical.

ACCESS Options
A number of Air Chemistry options could be viable for ACCESS, but they will depend on a balance between the acceptable levels of science for ACCESS versus the available resources (effort and computational). Besides the information and assumptions listed in previous Sections, it is assumed that it would be desirable for ACCESS to take a Unified Modelling approach wherever practical, in order to limit the number of models that would be supported by ACCESS. It is also assumed that Global applications are initially more critical than Regional applications, which are in turn initially more critical than Urban applications, especially given that the key
Urban application (tropospheric NWP) is already well served by the AAQFS CTM. These assumptions will help to minimize the resources needed for the options below.

The following Options are proposed over a 5-year period (e.g. Q3 2007 to Q2 2012) – looking further ahead than this in detail is probably not useful at the moment (see the Application Section above and the Comparison and Resources Sections below), given the current unknowns (organizational and resources) associated with ACCESS.

**Option 1: MOZART Global/Regional Scale & AAQFS CTM Urban Scale**

The Project Phases would be:

1. Over a 3-year period, develop and evaluate an inline model (using the UM framework for tracer advection and processes) consisting of combined MOZART V3 Stratospheric Chemistry and MOZART V4 Tropospheric Chemistry for Global NWP and ESM applications (see Table 2a)

2. Over a 2-year period, extend Phase 1 development and evaluation to Regional NWP and ESM applications, and use the regional predictions as boundary conditions for the Urban AAQFS CTM forecasts (see Table 2b)

A critical requirement of Phase 1 is the employment of:

- one contracted external Research Scientist with MOZART development experience (e.g. contracted for 3-years from NCAR, GFDL or MPI), with tasks that include
  
  i. in collaboration with other members of the Air Chemistry group (see below), provide coordination, training, advice, design and development expertise, to create a nestable, inline version of MOZART for ACCESS that includes tropospheric chemistry (from V4) and stratospheric chemistry (from V3)
  
  ii. connect the inline radiation modules needed for ACCESS (e.g. for actinic fluxes) based on modules in MOZART V3 and V4 (e.g. FTUV and the stratospheric equivalent)
  
  iii. connect the MOZART pre-processor to the ACCESS model, including the chemical compiler that will allow creation of suitable code for alternate species and chemistry schemes
  
  iv. provide advice on the connection of the standard MOZART inputs (e.g. global emission inventories) to the inline model
  
  v. provide advice and guidance during an initial evaluation of the ACCESS MOZART model on suitable evaluation datasets

The effort commonly needed for both Phases 1&2 is estimated to be three FTEs:

- one Research Scientist for model emission inventories and deposition processes, connectivity to some ACCESS modelling components, and development and evaluation for ESM applications at all scales, with tasks that include
  
  i. in collaboration with the ACCESS Aerosols group and the Land and Ocean Teams, develop and evaluate natural, biogenic and anthropogenic emission inventories for ACCESS Air Chemistry
  
  ii. in collaboration with the ACCESS Aerosols group and the Land and Ocean Teams, develop and evaluate wet and dry deposition processes for ACCESS Air Chemistry
  
  iii. in collaboration with the Cape Grim Program, develop and evaluate the model for ESM applications
iv. collaborate with members of the ACCESS Air Chemistry group on model evaluation for a range of applications and scales

- one Research Scientist for ACCESS MOZART development and evaluation for NWP applications, with tasks that include
  i. develop ACCESS inline tropospheric (gas and heterogeneous) chemistry from MOZART V4 for Global and Regional scales, in collaboration with the Aerosols group where necessary
  ii. obtain access to appropriate initial conditions (global chemical species analyses) for the model for NWP purposes (e.g. using potential products from the ACCESS Data Assimilation Team or from outside sources such as the GEMS Project)
  iii. in collaboration with AAQFS CTM developers, connect the AAQFS CTM to ACCESS for Urban NWP (replace meso-LAPS with UM)
  iv. evaluate and improve the ACCESS Air Chemistry model for NWP applications as needed

- one Research Scientist for ACCESS MOZART development and evaluation for Climate applications, with tasks that include
  i. develop ACCESS inline stratospheric (gas and heterogeneous) chemistry from MOZART V3 for Global and Regional scales, in collaboration with the Aerosols group where necessary
  ii. develop a condensed chemistry scheme in the ACCESS Air Chemistry model for tropospheric and stratospheric chemistry, suitable for Climate applications, using the pre-processor
  iii. develop and evaluate ACCESS-specific options and schemes in the ACCESS Air Chemistry model for Climate applications, in collaboration with the Aerosols group where necessary
  iv. develop and evaluate the ACCESS Air Chemistry model for IPCC applications

Table 2a. Proposed Option 1 (Phase 1) ACCESS model developed over a 3-year period (e.g. Q3 2007 to Q2 2010).

<table>
<thead>
<tr>
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<tr>
<td>ESM (Stratosphere)</td>
<td>MOZART inline</td>
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Table 2b. Proposed Option 1 (Phase 2) ACCESS model developed over a 2-year period (e.g. Q3 2010 to Q2 2012).

<table>
<thead>
<tr>
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Option 2: UKCA Global/Regional Scale & AAQFS CTM Urban Scale
The Project Phases would be:

1. Over a 2-year period, develop and evaluate an inline model (using the UM framework for tracer advection and processes) consisting of the UKCA tropospheric/stratospheric Chemistry model for Global NWP and ESM applications (see Table 3a), including ACCESS-specific options.

2. Over a 3-year period, extend Phase 1 development and evaluation to Regional NWP and ESM applications, including ACCESS-specific options, and use the regional predictions as boundary conditions for the Urban AAQFS CTM forecasts (see Table 3b).

The effort needed for both Phases 1&2 is estimated to be 3 FTEs, including a 0.50 FTE contribution to joint development work on UKCA:

- one Research Scientist for model emission inventories and deposition processes, connectivity to some ACCESS modelling components, and development and evaluation for ESM applications at all scales, with tasks that include:
  i. in collaboration with the ACCESS Aerosols group and the Land and Ocean Teams, develop and evaluate natural, biogenic and anthropogenic emission inventories for ACCESS Air Chemistry
  ii. in collaboration with the ACCESS Aerosols group and the Land and Ocean Teams, develop and evaluate wet and dry deposition processes for ACCESS Air Chemistry
  iii. in collaboration with the Cape Grim Program, develop and evaluate the model for ESM applications
  iv. collaborate with members of the ACCESS Air Chemistry group on model evaluation for a range of applications and scales
- one Research Scientist for ACCESS UKCA development and evaluation for NWP applications, with tasks that include:
  i. evaluate and develop the ACCESS Air Chemistry model for NWP Global and Regional scales, in collaboration with the Aerosols group where necessary
  ii. collaborate (0.25 FTE) with UKMO(NWP)/UKCA Scientists on agreed joint Air Chemistry work
  iii. develop and evaluate ACCESS-specific options and schemes in the ACCESS Air Chemistry model for NWP applications, in collaboration with the Aerosols group where necessary
  iv. in collaboration with AAQFS CTM developers, connect the AAQFS CTM to ACCESS for Urban NWP (replace meso-LAPS with UM)
  v. obtain access to appropriate initial conditions (global chemical species analyses) for the model for NWP purposes (e.g. using potential products from the ACCESS Data Assimilation Team or from outside sources such as the GEMS Project)
- one Research Scientist for ACCESS UKCA development and evaluation for Climate applications, with tasks that include:
  i. evaluate and develop the ACCESS Air Chemistry model for Climate Global and Regional scales, in collaboration with the Aerosols group where necessary.
ii. collaborate (0.25 FTE) with UKMO(Climate)/UKCA Scientists on agreed joint Air Chemistry work

iii. develop and evaluate ACCESS-specific options and schemes in the ACCESS Air Chemistry model for Climate applications, in collaboration with the Aerosols group where necessary

iv. develop and evaluate the ACCESS Air Chemistry model for IPCC applications as needed

Table 3a. Proposed Option 2 (Phase 1) ACCESS model developed over a 2-year period (e.g. Q3 2007 to Q2 2009).

<table>
<thead>
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Table 3b. Proposed Option 2 (Phase 2) ACCESS model developed over a 3-year period (e.g. Q3 2009 to Q2 2012).

<table>
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**A Brief Comparison of the Options**

Common features of both Options over the next 5 years are

- a Unified Air Chemistry modelling approach for NWP and ESM applications for all scales
- distinctive differences (after 5 years) between the UK and Australian Air Chemistry models, including
  - different model inputs and deposition processes, such as the use of alternate emission inventories and online emissions (e.g. from CABLE), incorporating Australian datasets at the Regional and Urban scales
  - ACCESS-specific options and chemistry schemes
  - an Australian Urban tropospheric NWP capability (AAQFS CTM)
  - Australian Air Chemistry expertise (3 Scientists) within ACCESS

The main advantages of Option 1 (ACCESS-MOZART) over Option 2 are

- From the outset, there is an identifiable difference in ACCESS Air Chemistry compared to the UM UKCA system, including model and chemistry, as well as global emission inventories
- The Phase 1 ACCESS Air Chemistry model will be more comprehensive than the UKCA Scheme, potentially allowing more immediate suitability for NWP applications
• MOZART has been around for a number of years now, and has a larger and more complete set of evaluation studies backing the model for Global applications.

The main advantages of Option 2 (ACCESS-UKCA) over Option 1 are:
• Less resources will be required for Option 2 (1 FTE less, over first 3-years).
• The Phase 1 ACCESS Air Chemistry model will be more condensed than the MOZART Scheme, potentially allowing more immediate suitability for Climate applications.
• Less initial risk is associated with Option 2 (ACCESS UKCA), as a pre-connected inline model will initially be available for ACCESS.
• Option 2 will be about 1-year ahead of Option 1 after 5-years, although this may depend on how much more comprehensive the UKCA chemistry needs to be for NWP or ESM applications.
• Option 2 will provide increased collaboration with the UKMO, with 0.50 FTE being provided for joint development of UM/UKCA for NWP and ESM Air Chemistry applications.

ACCESS Resources
Both Options presented in this discussion paper require a base effort of 3 FTEs over 5 years (with Option 1 requiring an additional 1 FTE over the first 3 years), and it is likely that enough expertise in the NWP, Climate and Air Pollution areas within CSIRO and BMRC may be available for these positions to be filled by secondment of existing Research Scientist staff, although this will depend on competing priorities and projects within these organizations, and the organizational structure of ACCESS.

Following-on from the 5-year timeframe considered here, ACCESS Air Chemistry will need ongoing effort spent on the tasks identified, but it may also consider (with increased FTEs) also focusing more on Urban scales and other applications such as Emergency Response, hind-casting or regulatory applications.

Acknowledgements
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