Integrated modelling systems in Australia

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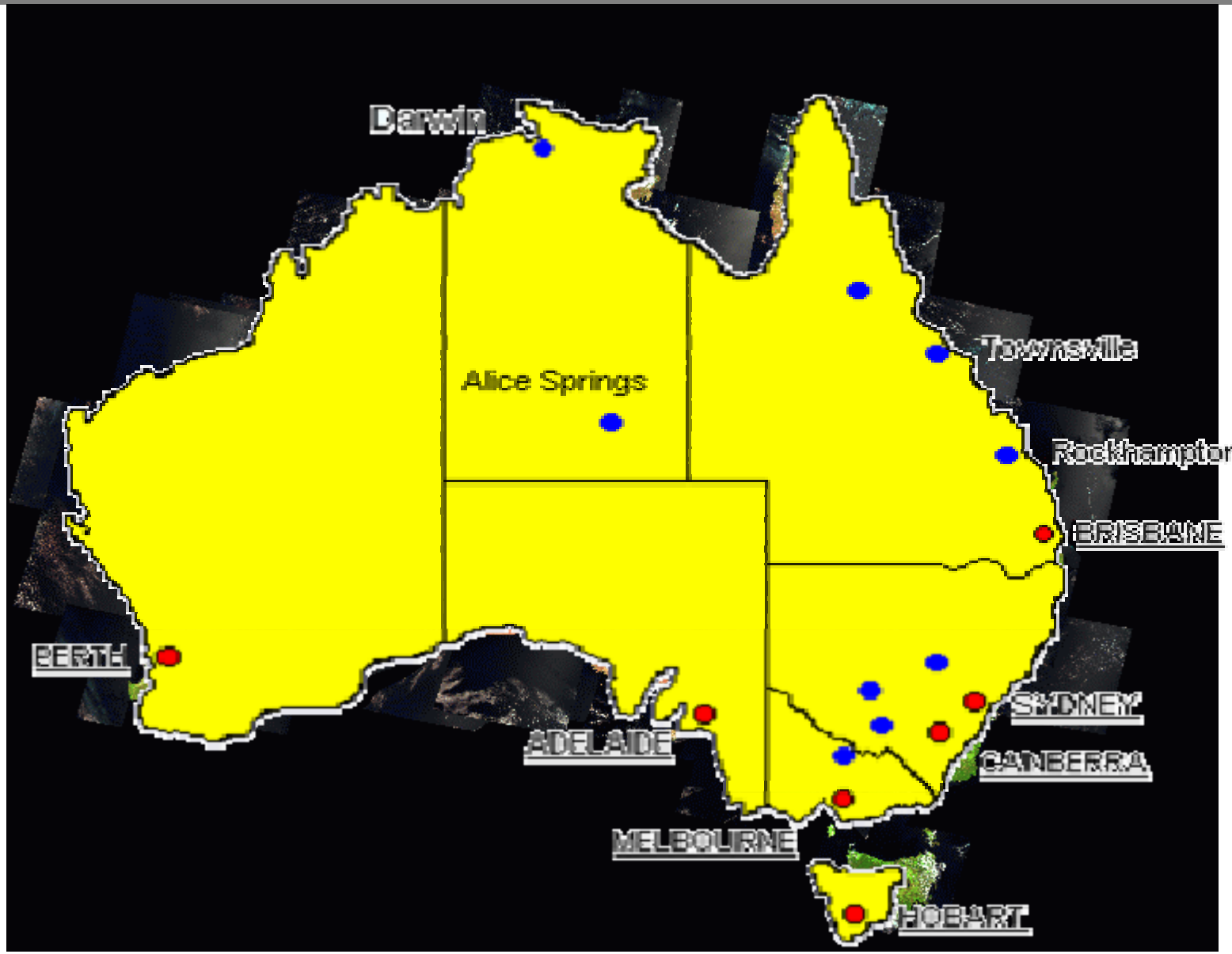
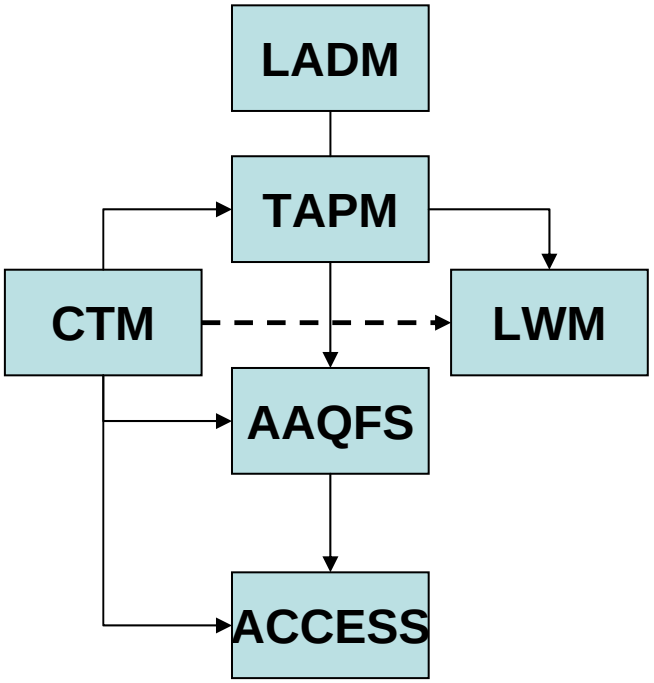
www.csiro.au

The Plan

- Australia in context
- LADM – our first coupled Mesoscale Meteorological + Lagrangian particle model (off-line)
- TAPM – *in-line* coupled comprehensive *PC-based* Meteorological and Lagrangian/Eulerian chemical transport model
  - TAPM-CTM — Extension to complex chemistries (CB 2005)
  - LWM model for road-scale effects
- AAQFS – operational BoM NWP + TAPM-CTM (supercomputer, off-line)
- ACCESS – starting Earth System Science model with HADGEM in collaboration with Hadley Centre
- Mention experiences along the way

AUSTRALIA IN CONTEXT





LADM

www.csiro.au

First CSIRO integrated System

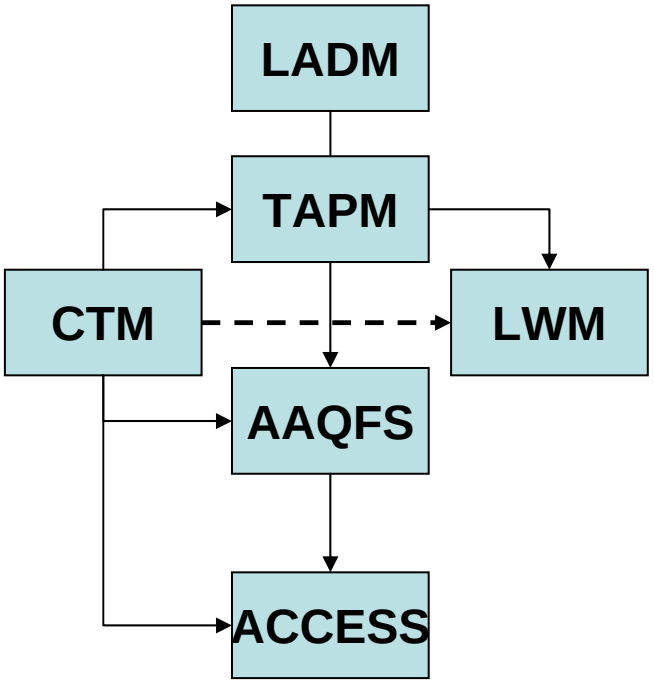
Started in 1986 by off-line coupling of Pielke mesoscale model with McNider particle model.

A specially developed NWP model + Lagrangian particle model → LADM (again off-line)

Visualisation has proven to be a key to usability and communicating results

Rapidly learnt that:

- **Recirculation of pollutants to a region is very important in our setting**
- **High resolution for the accurate timing and location of the sea breeze is vital for success against data.**



TAPM

www.csiro.au/tapm

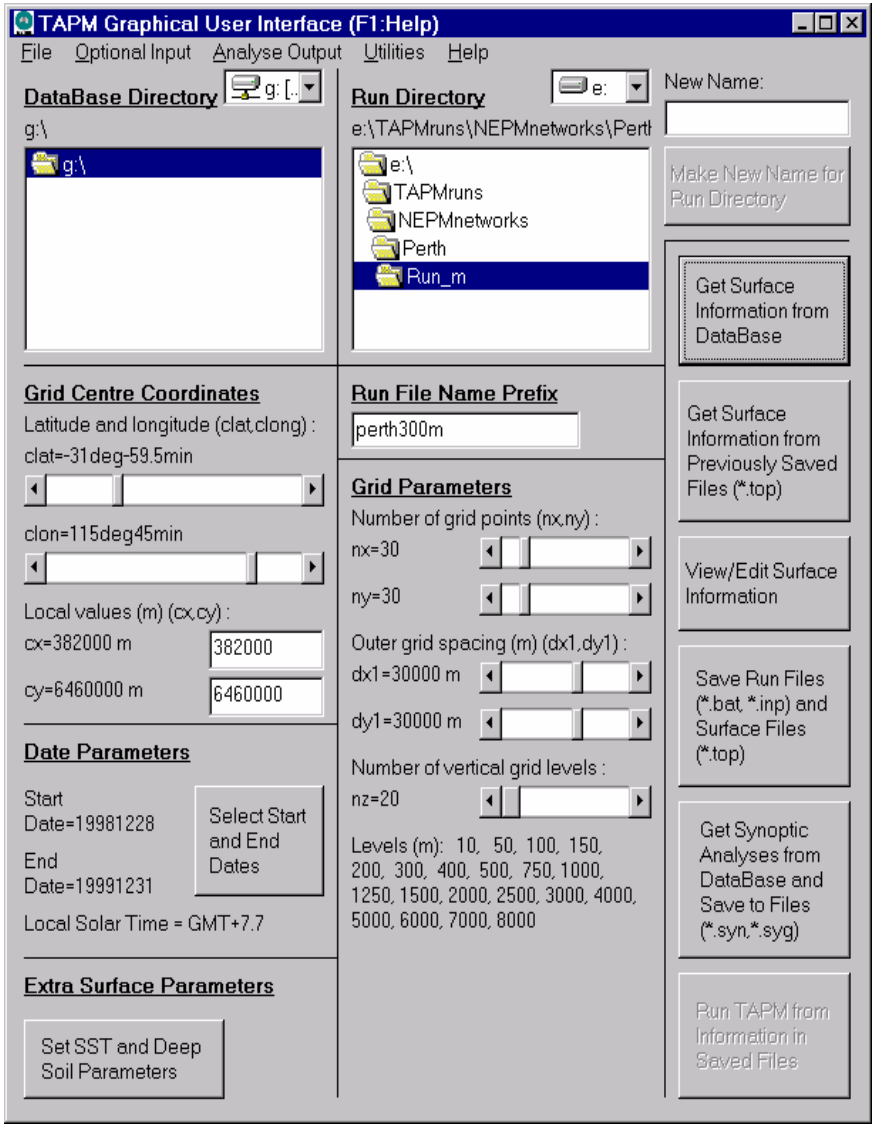
TAPM DESCRIPTION

Predicts both meteorology and air quality for a period of a day to a year or more with hourly results on grids down to 300 m spacing

Runs on a PC using a GUI or on a cluster via scripts

The GUI sets up grids, runs model and post-processes results

Gridded terrain, land-use and 6-hourly synoptic 3D analyses of meteorology on CDs



Model Description

The Air Pollution Model (TAPM)

- Meteorology
  - 3-D, Eulerian, nestable;
  - incompressible, non-hydrostatic;
  - winds, temperature, pressure, water vapour, cloud and rain water, turbulence kinetic energy and eddy dissipation rate;
  - surface scheme (soil and vegetation);
  - cloud microphysics scheme;
  - radiation scheme;
  - wind data assimilation.

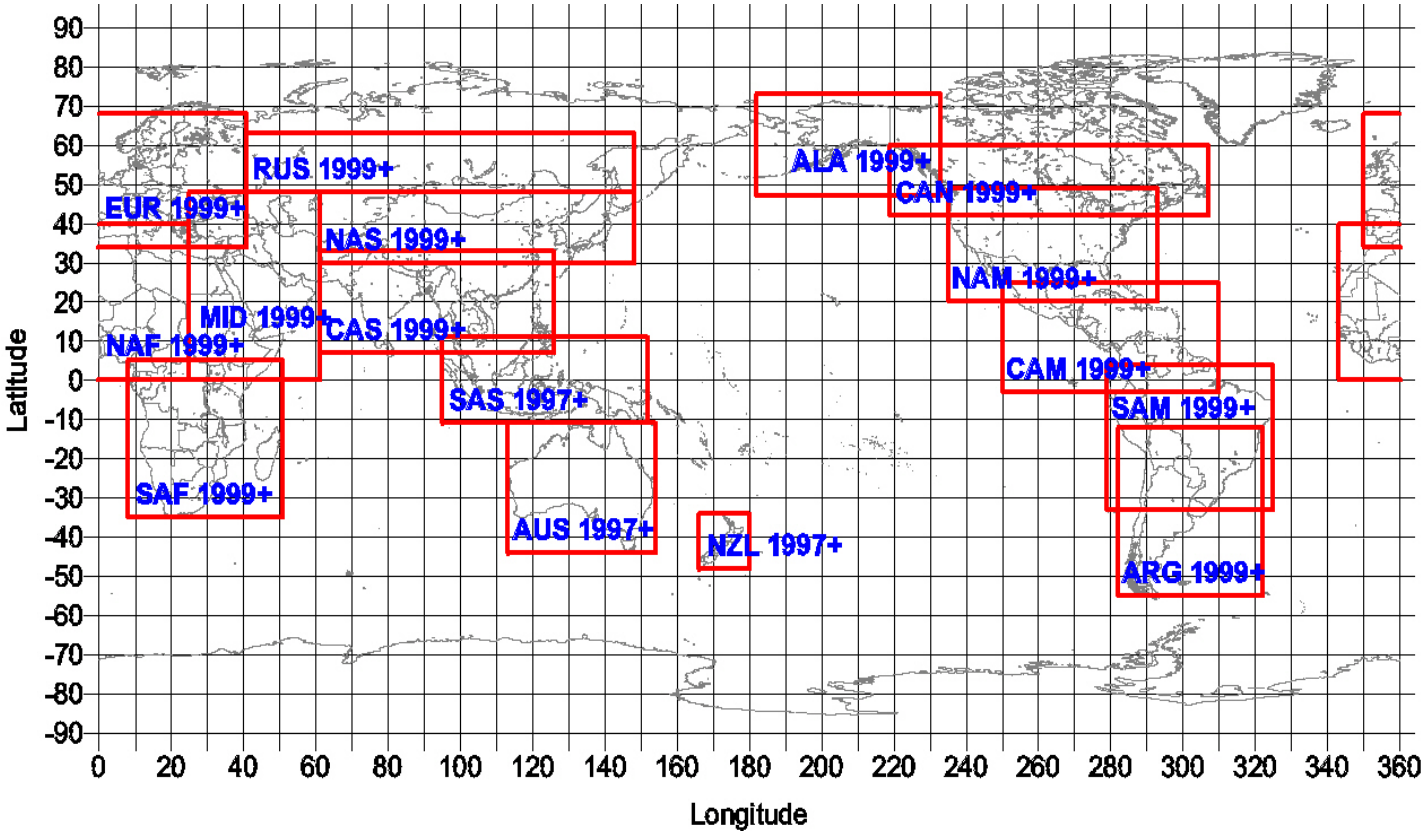
Model Description

The Air Pollution Model (TAPM)

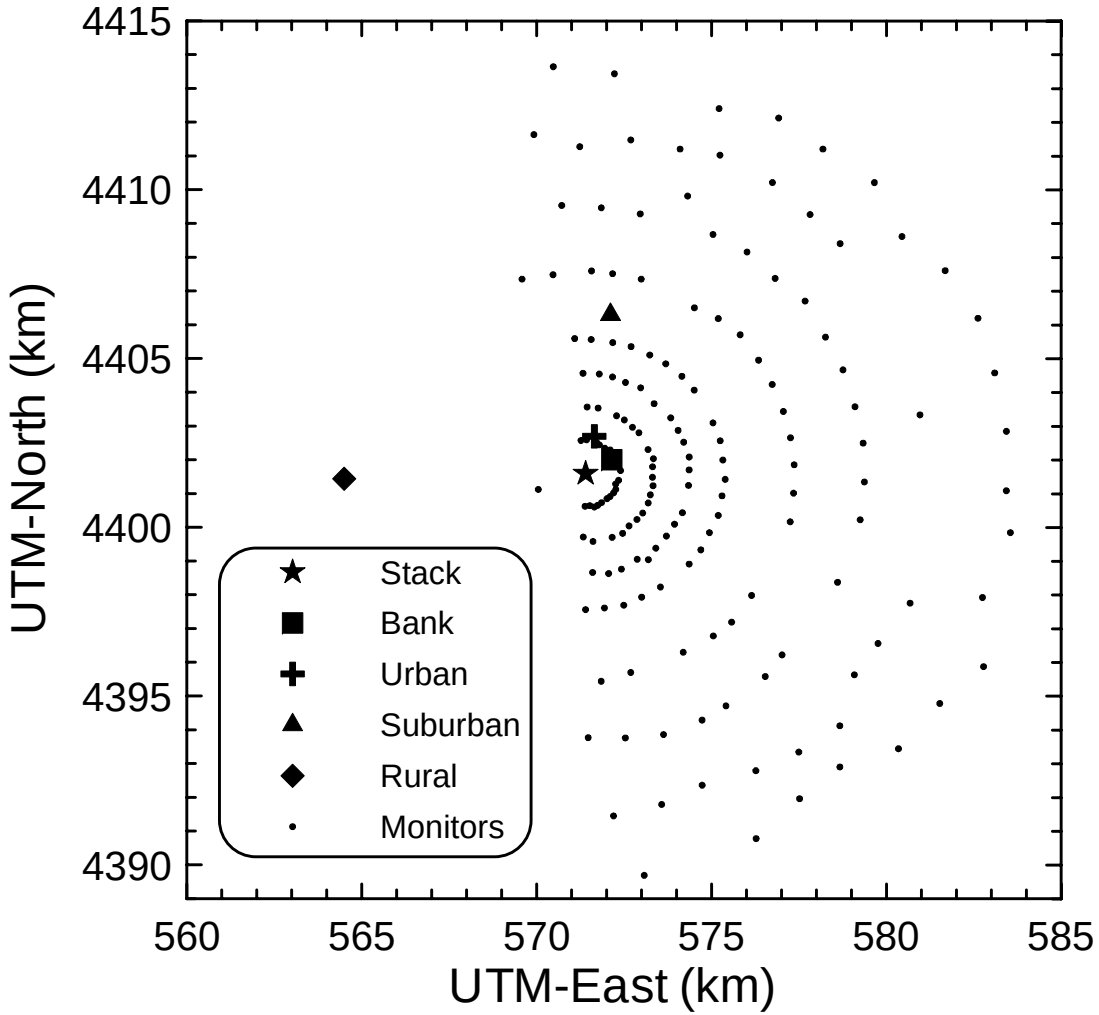
- Air Pollution
  - 3-D, Eulerian, nestable;
  - tracer or multiple pollutant modes;
  - Lagrangian particle module;
  - plume rise & building wakes;
  - simplified photochemistry (GRS);
  - aqueous chemistry;
  - wet and dry deposition;
  - emissions from point, line, area & gridded sources.

Tiles for TAPM data files

supplied on CD



Indianapolis USA
International Tracer Dataset



Indianapolis USA
International Tracer Dataset

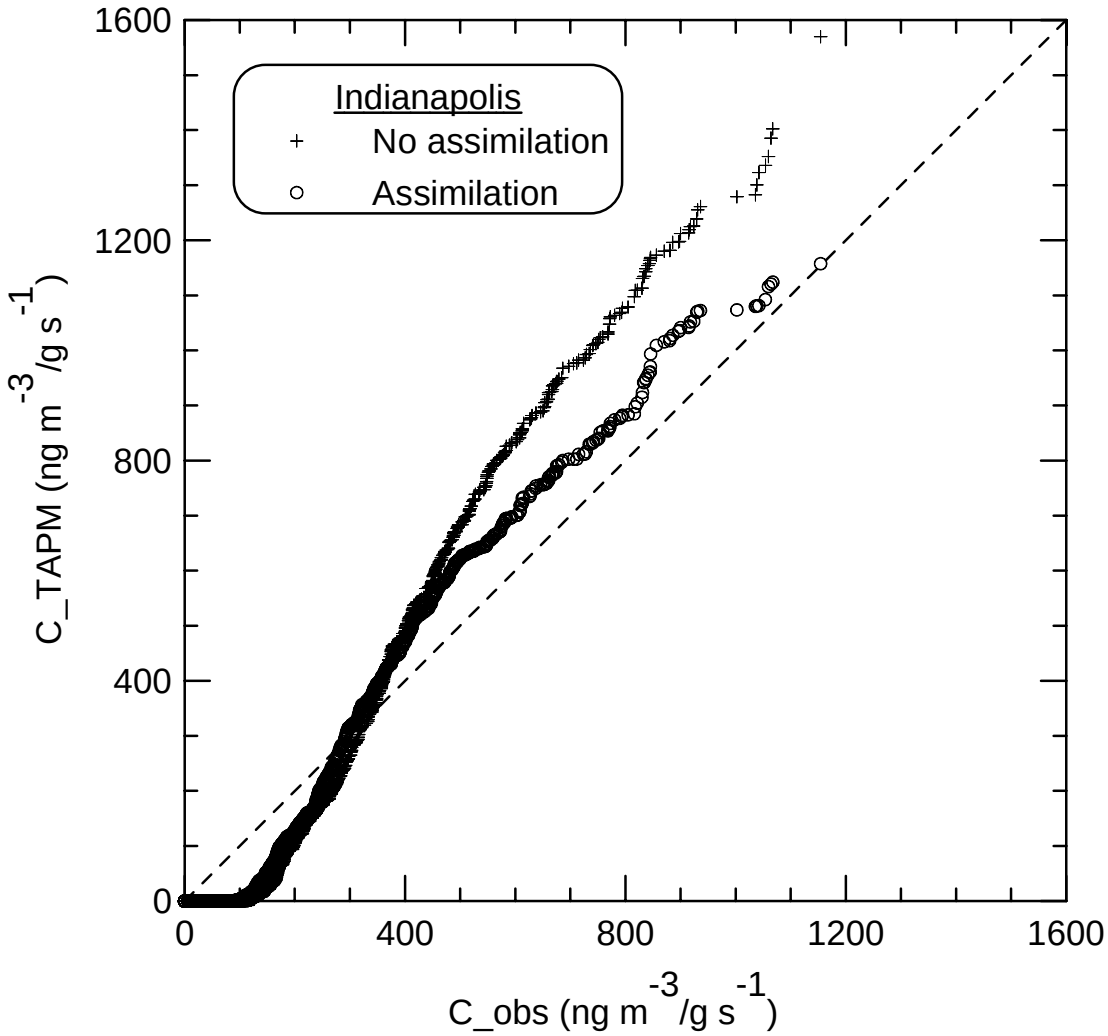
Model performance statistics for Indianapolis, Quality 2&3 (N_{obs} = 1216)

Relevant units ng m^{-3} $(g\ s^{-1})^{-1}$	Mean	Sigma	Bias	NMSE	Cor	Fa2
C_OBS	258	222	0.0	0.0	1.00	1.00
TAPM	261	335	-2.8	1.4	0.46	0.32
TAPM-A	248	284	9.6	1.0	0.51	0.36
ISCST3	404	321	-146.4	1.4	0.16	0.45
AERMOD	225	196	33.2	1.3	0.17	0.41
ADMS3	265	255	-7.5	1.3	0.26	0.42

NMSE = normalised mean square error, Cor = correlation coefficient, Fa2 = factor of two
TAPM with no data assimilation
TAPM-A with data assimilation

Model Evaluation

Indianapolis Quantile-Quantile Plot (Arc-wise MAX) (2 & 3 data)

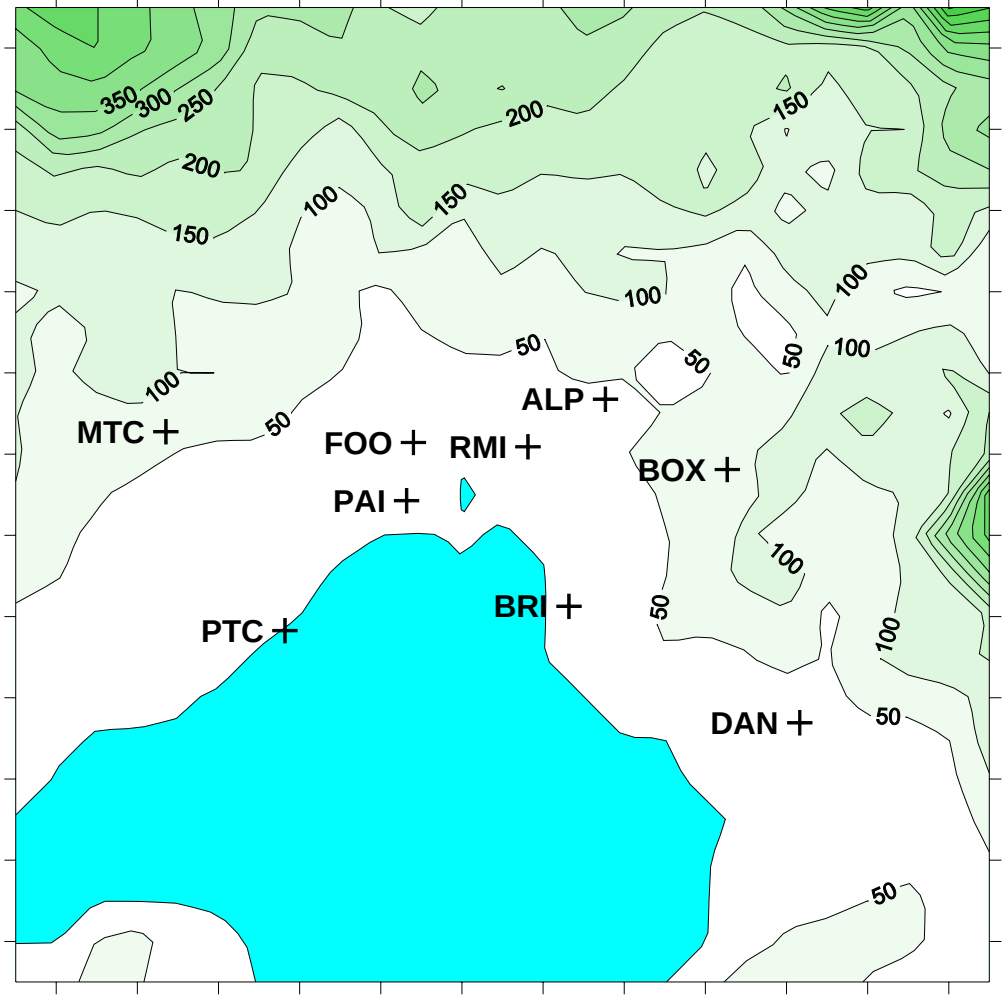


Melbourne Urban Region

Melbourne Region (TAPM inner grid domain)

3 million people dominantly motor vehicle pollution

75 km domain
3 km grid

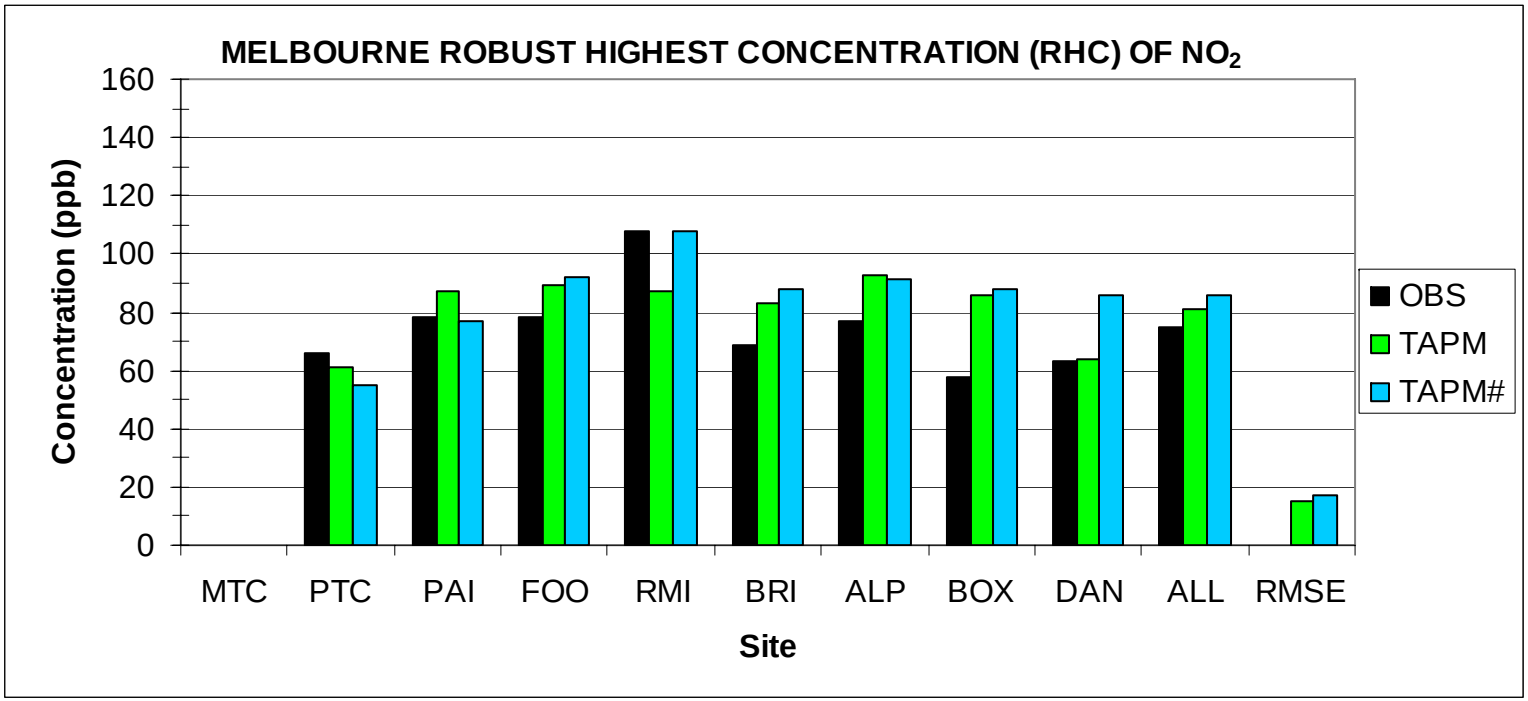


Results (1hr x 1year) – Meteorology

	MEAN OBS ($m\ s^{-1}$/°C)	MEAN MOD ($m\ s^{-1}$/°C)	STDEV OBS ($m\ s^{-1}$/°C)	STDEV MOD ($m\ s^{-1}$/°C)	RMSE ($m\ s^{-1}$/°C)	IOA (>0.5 good) (1=perfect)
WS10	3.3	3.5	1.9	1.8	1.4	0.85
U10	0.8	1.1	2.1	2.2	1.6	0.86
V10	0.3	0.1	3.0	3.1	1.7	0.92
T2	14.6	14.8	5.9	6.4	2.4	0.95

Statistics averaged over all EPA Victoria sites, for the **TAPM simulation without wind data assimilation**.

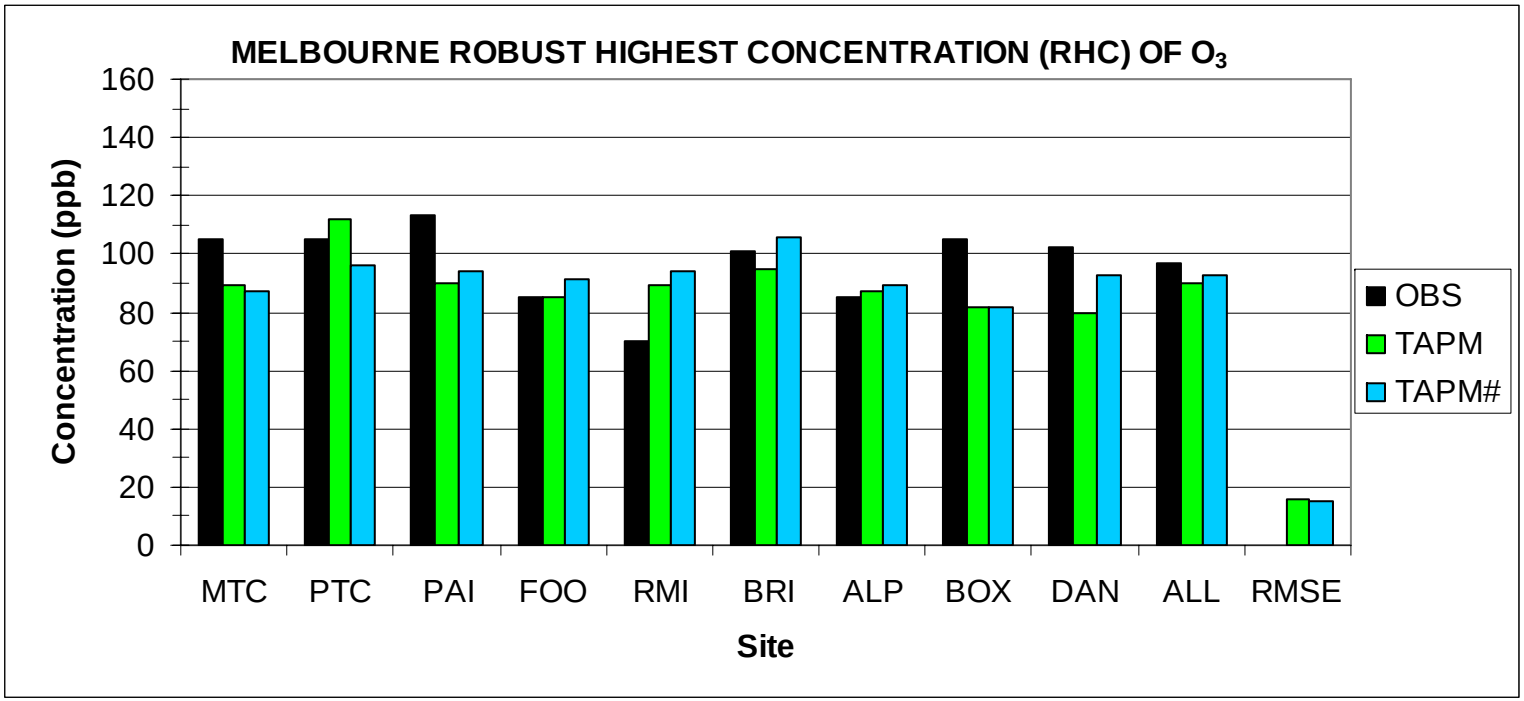
Results (1hr x 1year) – Nitrogen Dioxide



TAPM – without wind data assimilation

TAPM# – with wind data assimilation

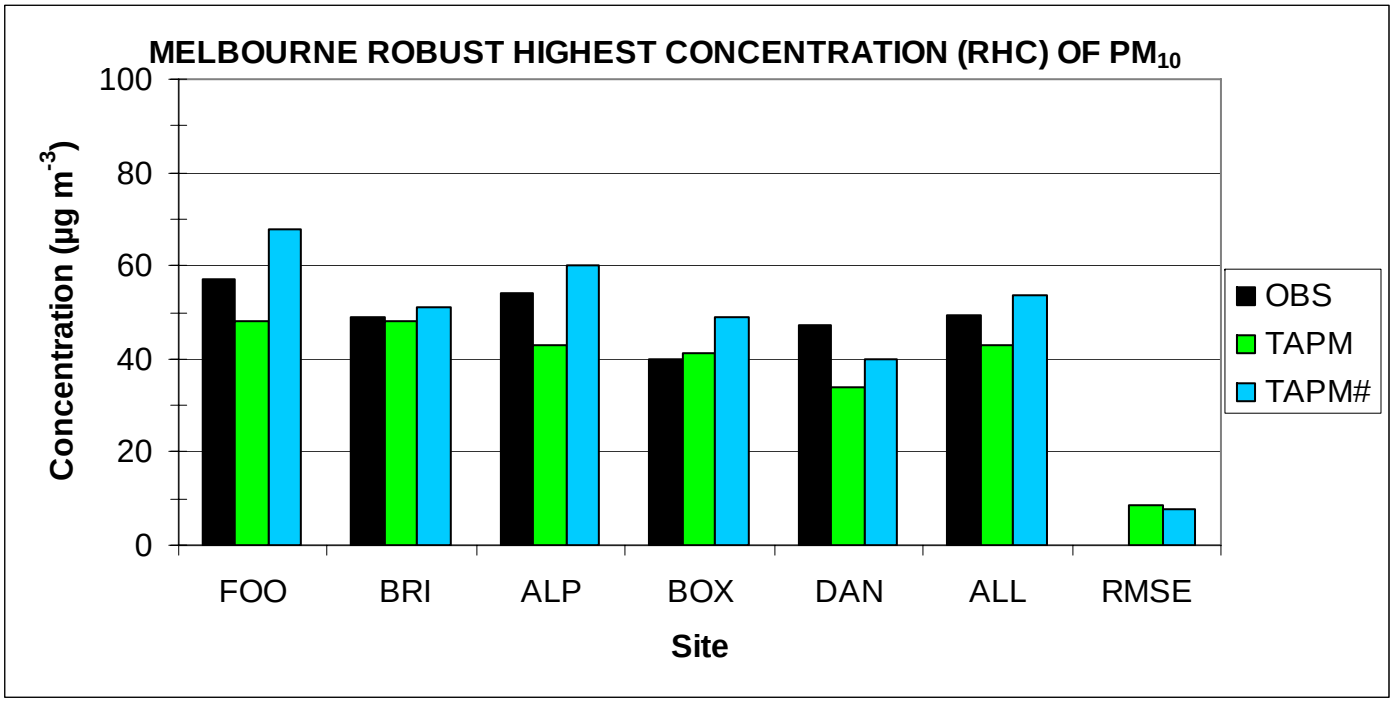
Results (1hr x 1year) – Ozone



TAPM – without wind data assimilation

TAPM# – with wind data assimilation

Results (1hr x 1year) – PM_{10} (24hr ave.)



TAPM – without wind data assimilation

TAPM# – with wind data assimilation

Summary

TAPM is based on complete equations

PC-based and easy to use

Predicted meteorology for almost any region

Non-reactive and photochemical pollutants

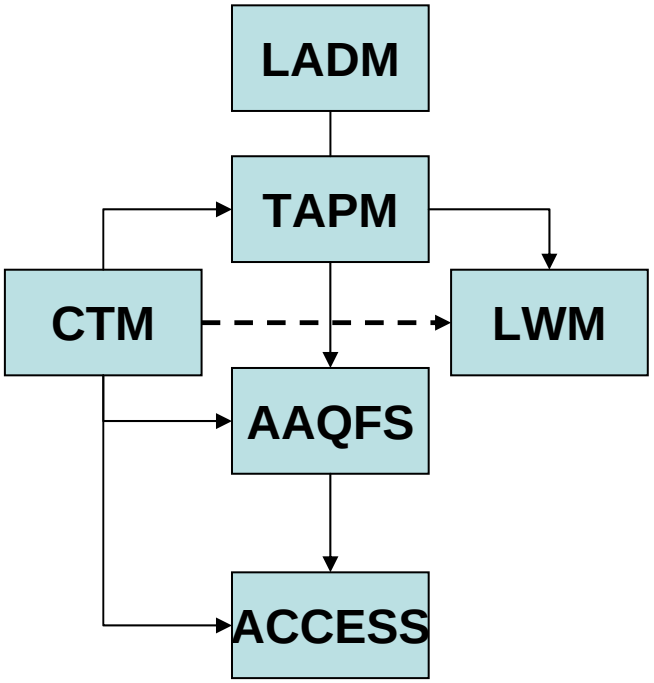
Discrete sources: point, line , area/volume

Gridded emissions: biogenic, industrial, vehicle, commercial/domestic, wood-heater sources

Verified for meteorology and air pollution in many studies

Used by 90 Licensed Groups in 18 countries: 154 licences

Web: http://www.cmar.csiro.au/research/tapm/index.html



TAPM-CTM

CSIRO

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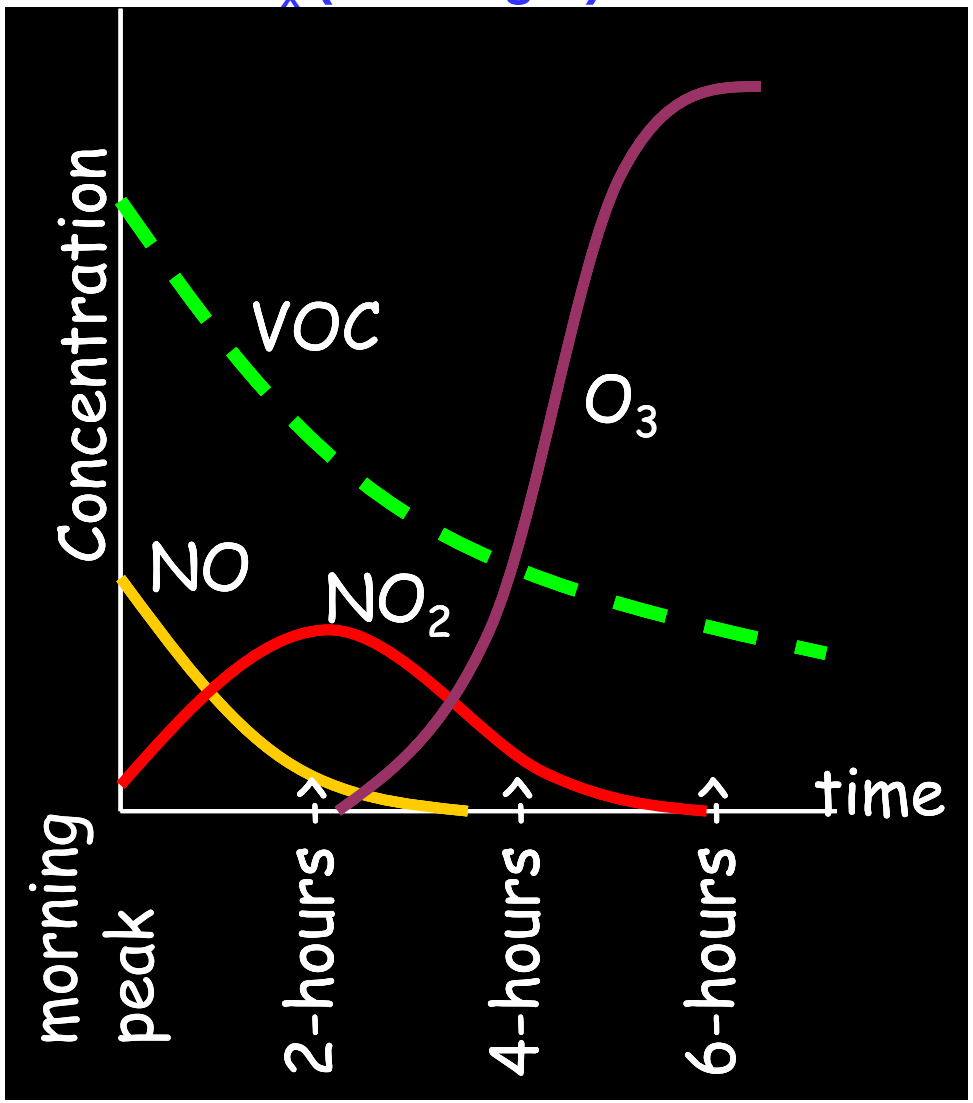
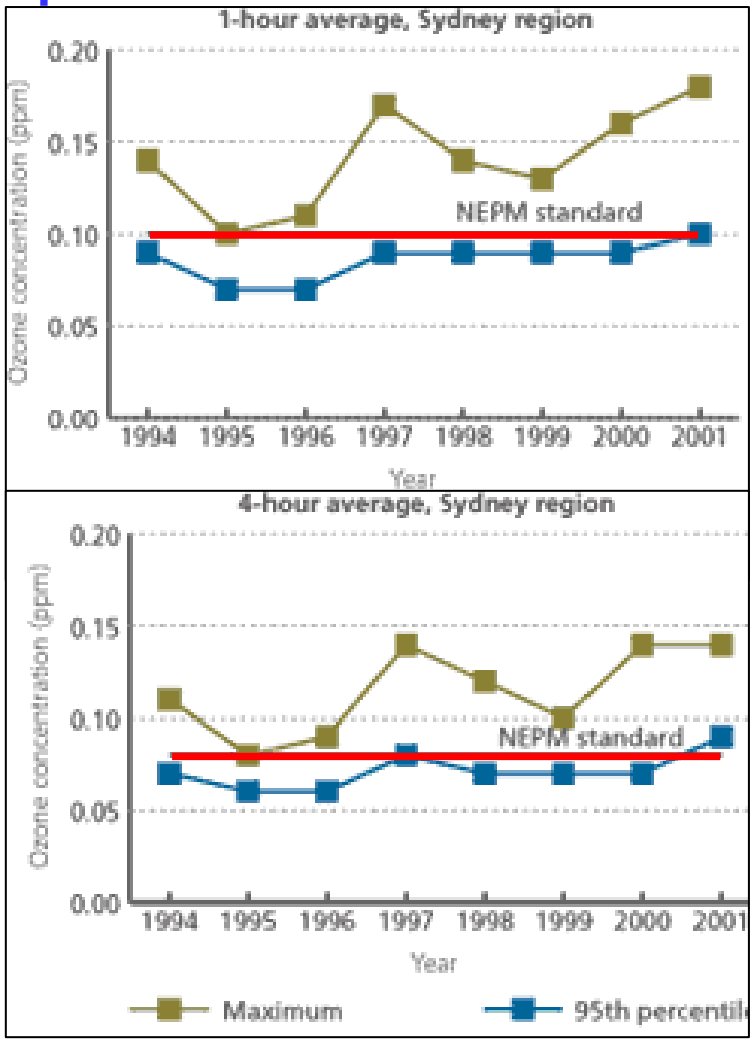
Photochemistry – the Sydney problem

VOC + NO_x (+ sunlight) → ozone + other products



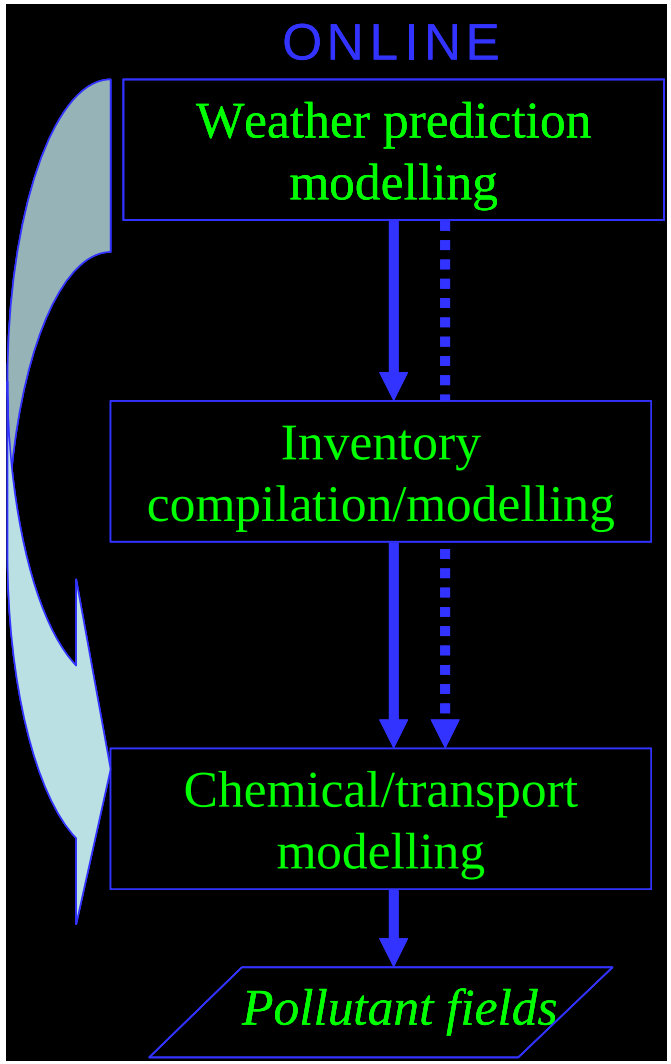


http://www.epa.nsw.gov.au/soe/soe2003

Sydney Seasonal Photochemistry Modelling System

Require a system with the ability to model meteorology, emissions and chemical transformation over hourly to seasonal time scales:

- TAPM meteorology +
- Extended chemistry
  - Carbon Bond 2005 – 51 species, 155 reaction pathways



Modelling Configuration for a Study

Grid system
60 x 70 (12, 6, 3 km);
12 km domain height (TAPM);
4 km domain height (CTM);

Integration period
3 x 5 month simulations
(November-March)
2000/2001; 2003/2004; 2004/2005;

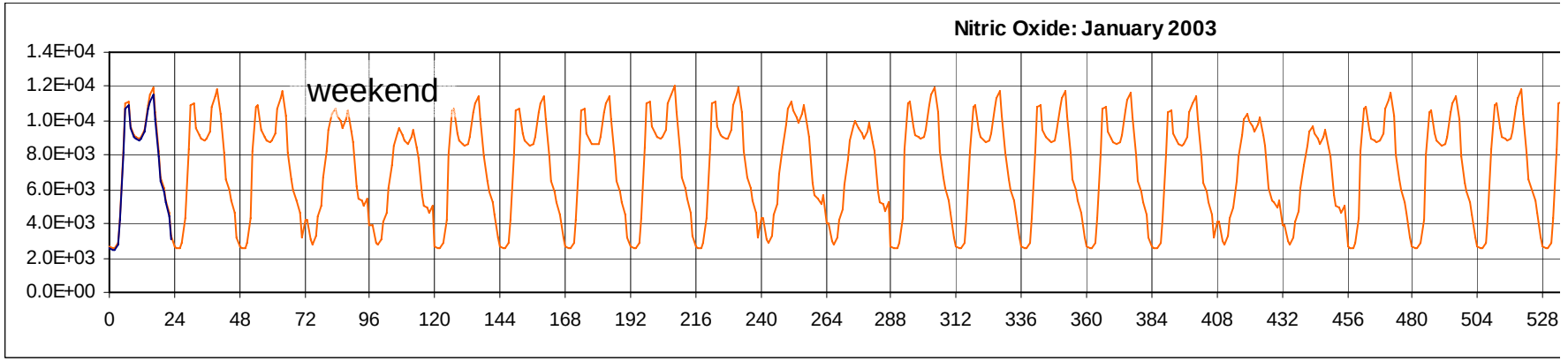
Initial and boundary conditions
GASP (BoM global NWP)
- Assimilate winds from 115 near-surface sites

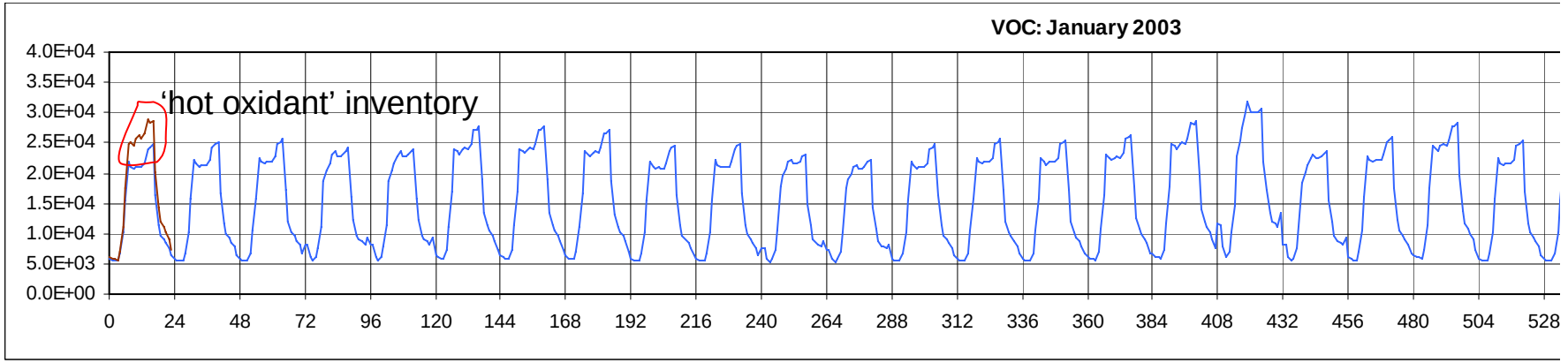
Computation
15 processors on HPCC Linux Cluster
48 h wall-clock per simulated month
0.5 terabyte data storage

6-km spaced grid and locations of near-surface wind observation sites

Anthropogenic Emissions

Vary anthropogenic emissions with temperature (and weekday/weekend)





Nitric oxide emissions show typical traffic-based diurnal variation; VOC emissions show stronger temperature variability with afternoon peak due to enhanced traffic evaporatives under higher ambient temperatures

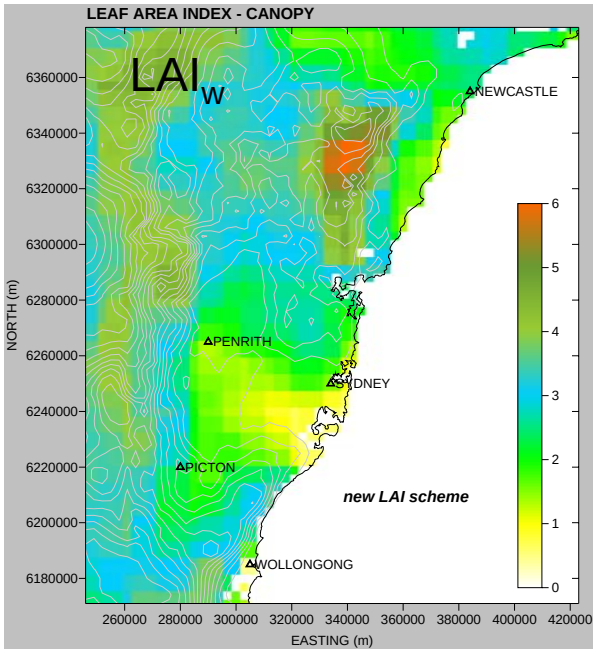
Biogenic Emissions- up-scaling

Canopy

q_{st} = *f*(T) x 25 μg-C $g^{-1}h^{-1}$ (eucalypt)

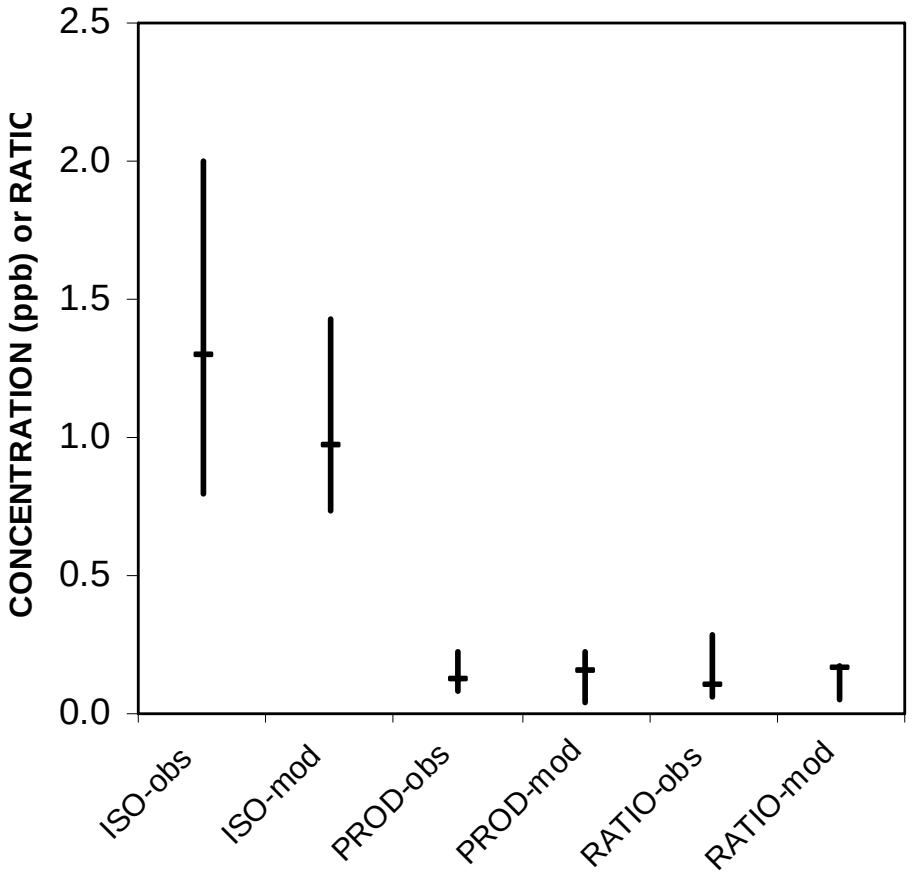
B_m=100 x LAI_w(*x*,*y*) g m^{-2};

h_c=function of land-use category;



LAI_w = wooded land-use

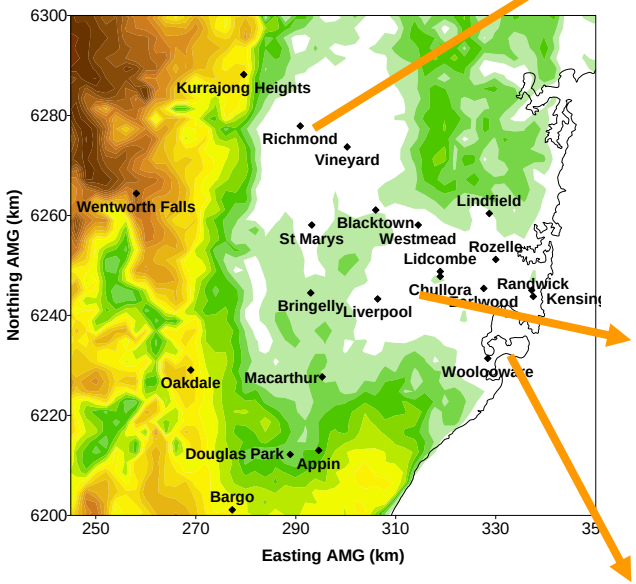
Observed and modelled in-canopy isoprene and oxidation products

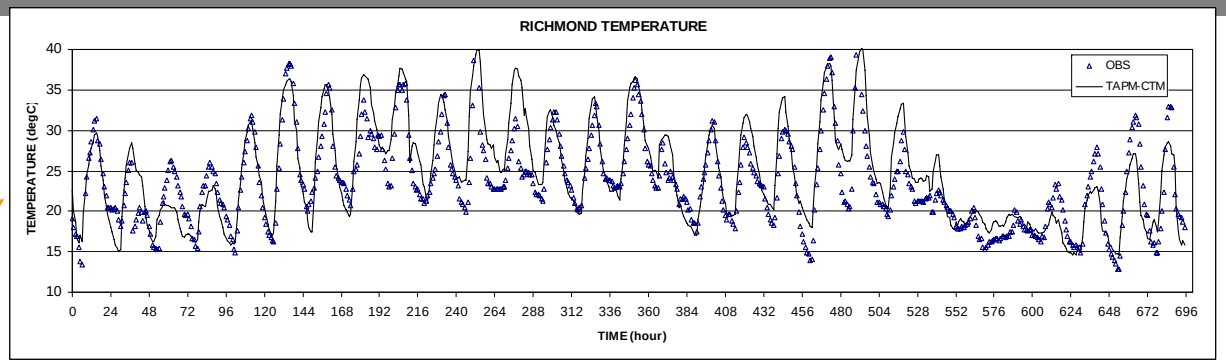


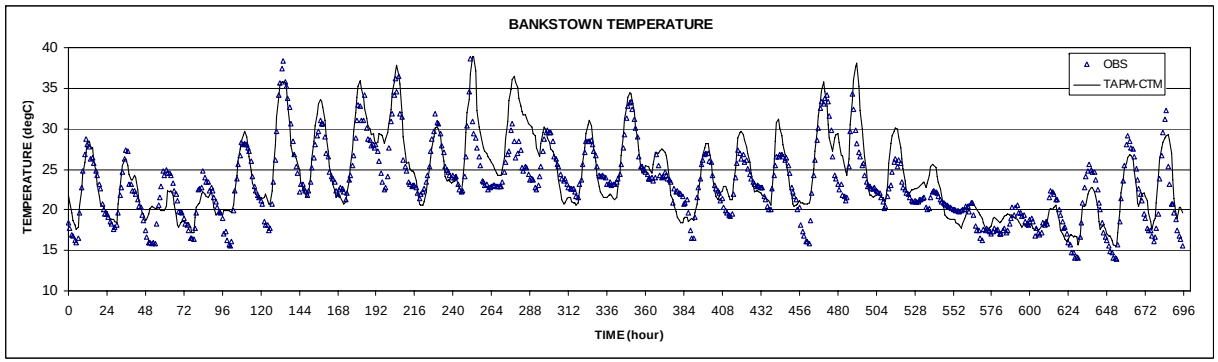
http://www.cmar.csiro.au/e-print/open/cope_2005c.pdf

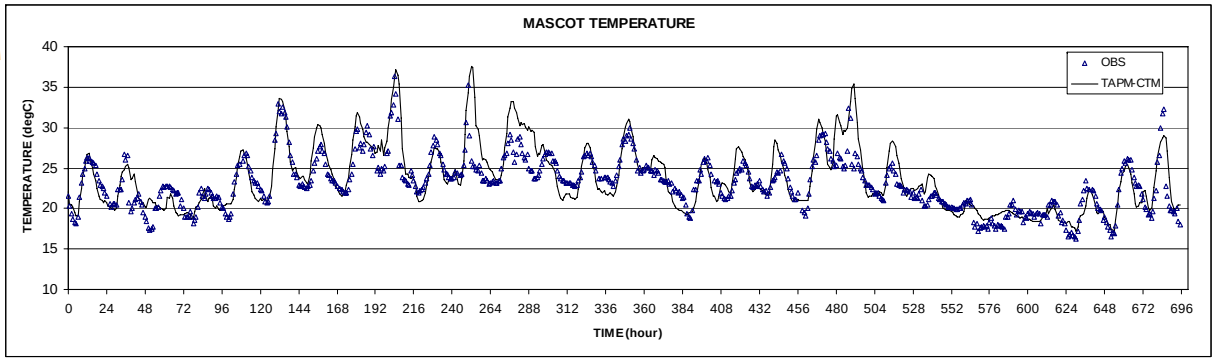
Model performance: Temperature

February 2004



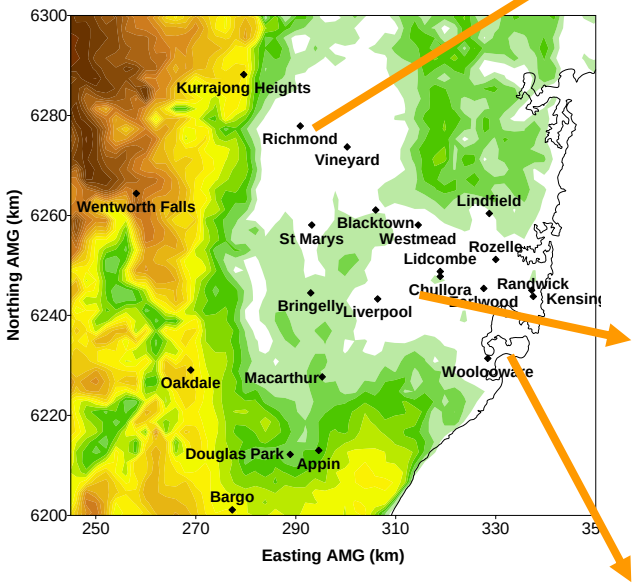


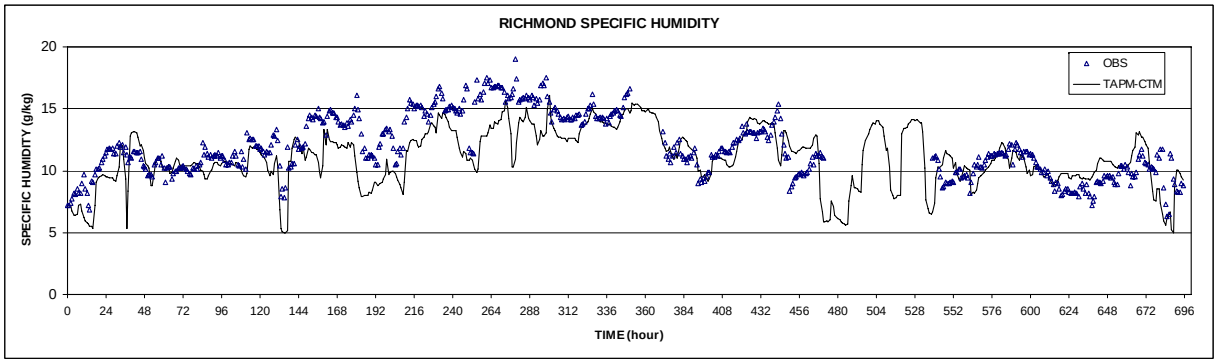


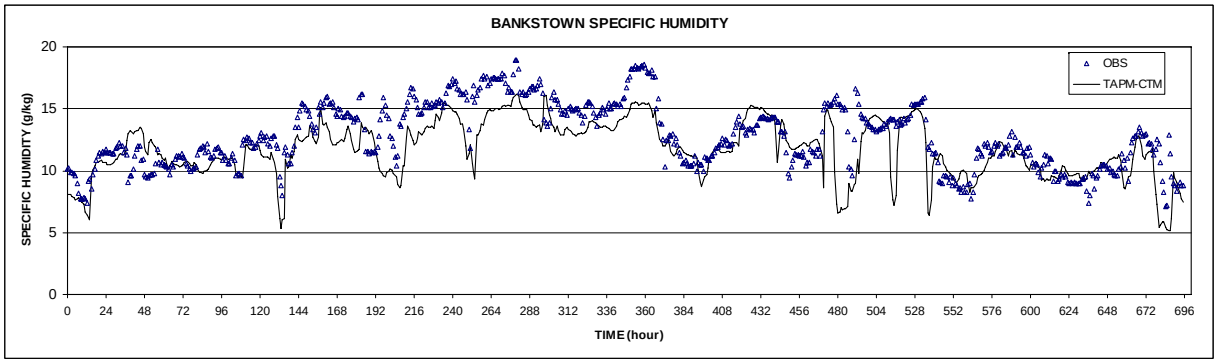


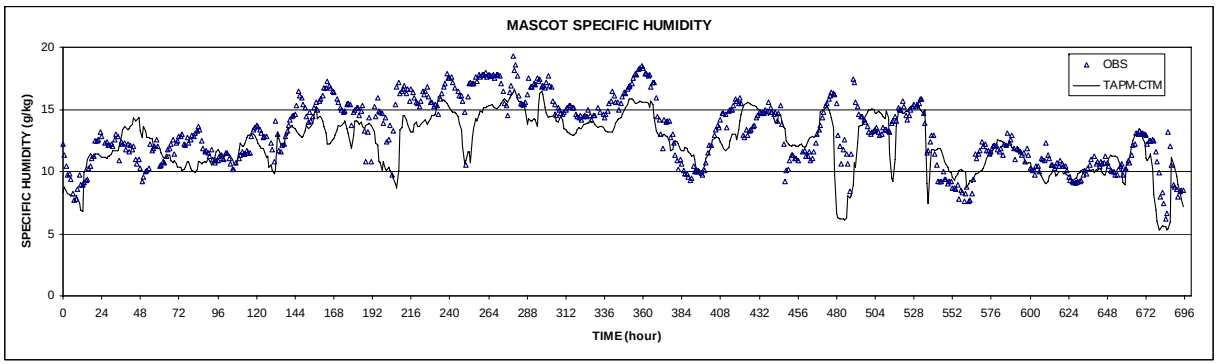
Model performance: Specific humidity

February 2004



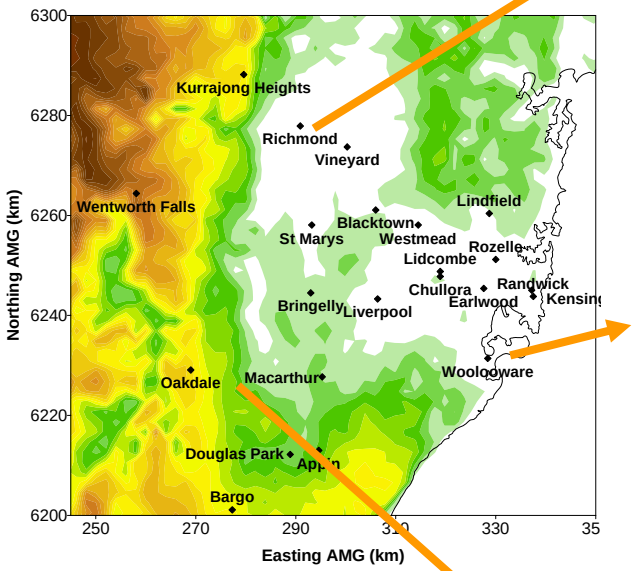


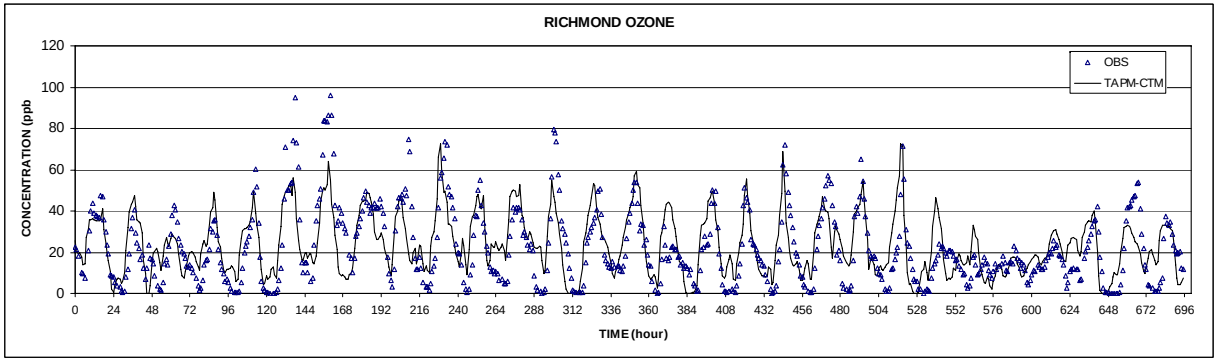


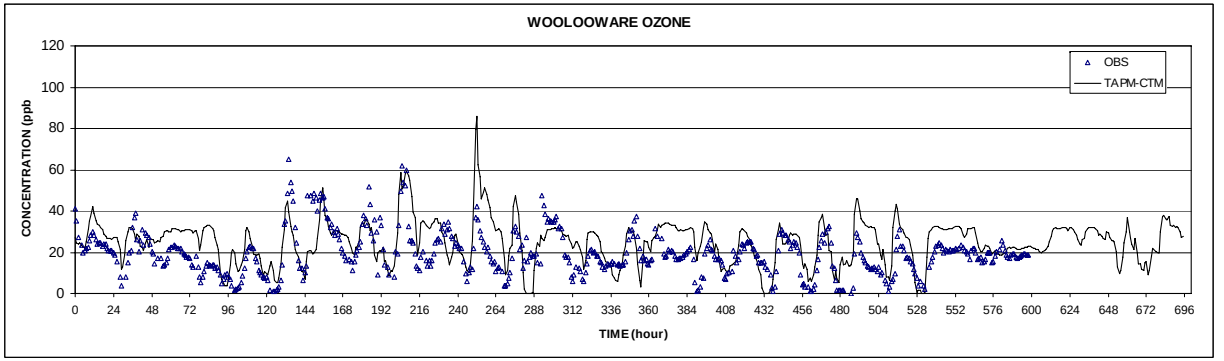


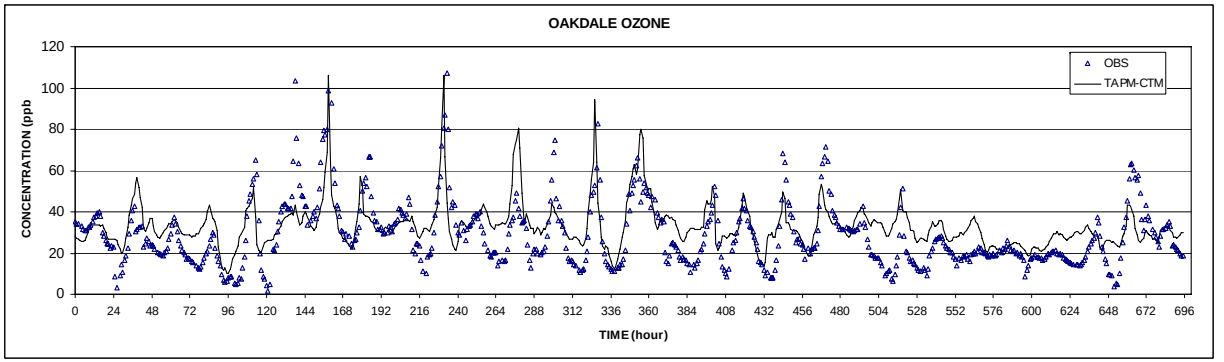
Model performance: 1-hour ozone

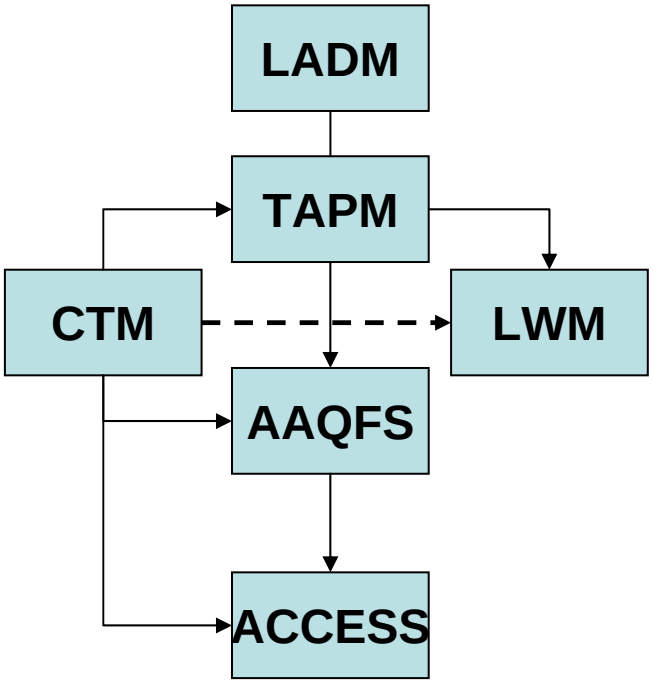
February 2004











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Lagrangian Wall Model

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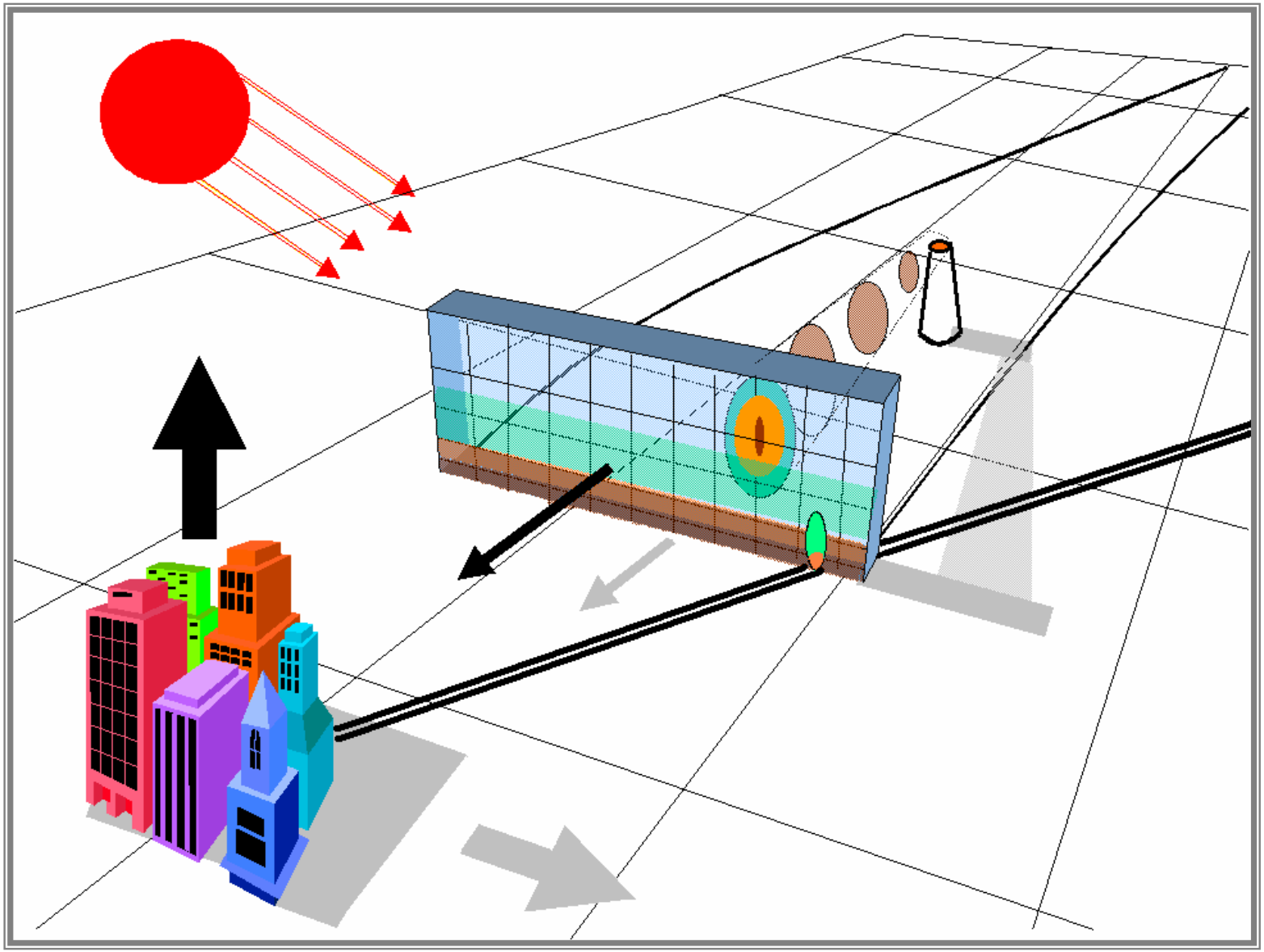
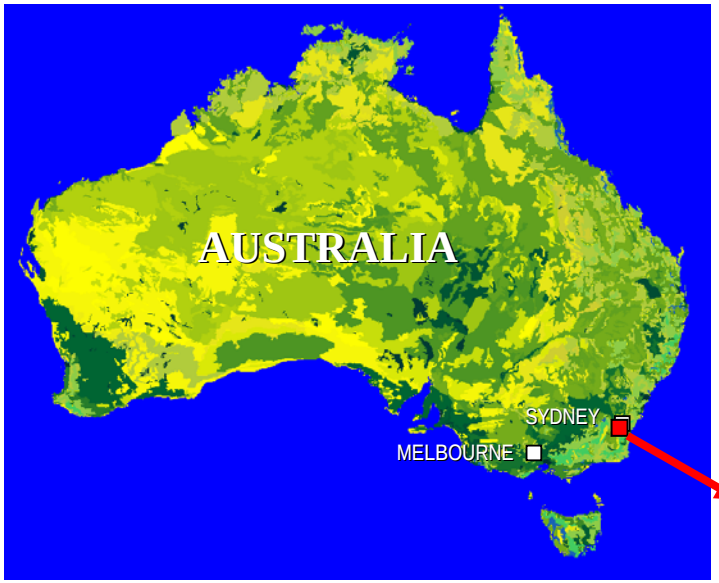
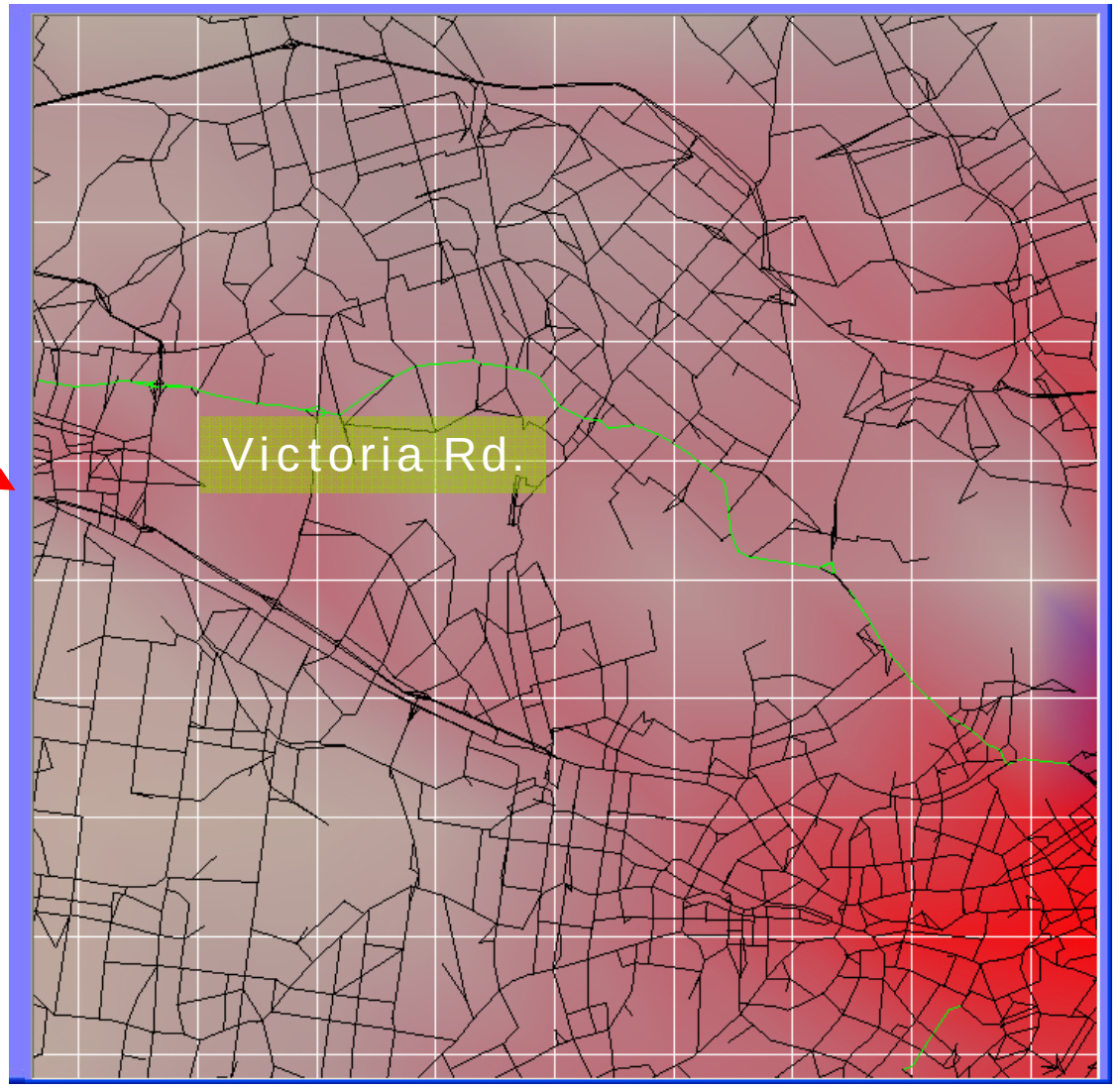
Near-Road Air Quality Modelling – the Lagrangian Wall Model



Urban scale air pollution impact



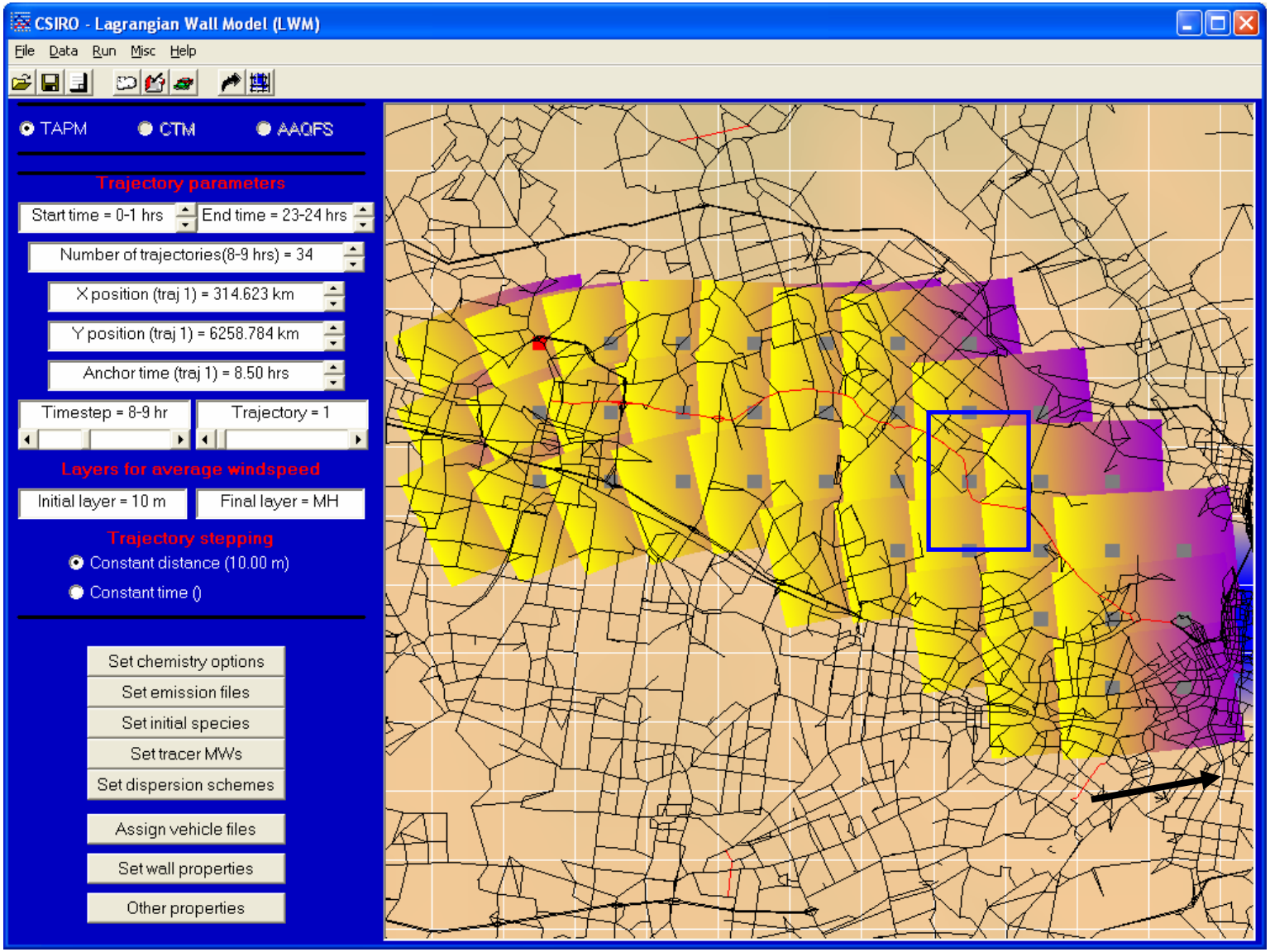


TAPM SIMULATION

- **2-km computational grid**
- **15,000 link emissions motor vehicles**
- **MAQS inventory- other sources**

- **1-h CO at 09 winter day**
- **modelled CO 400-700 ppb**
- **1-h PM10 similar**
- **Modelled PM10 to 20 µg/m^3**

Overlapping trajectories

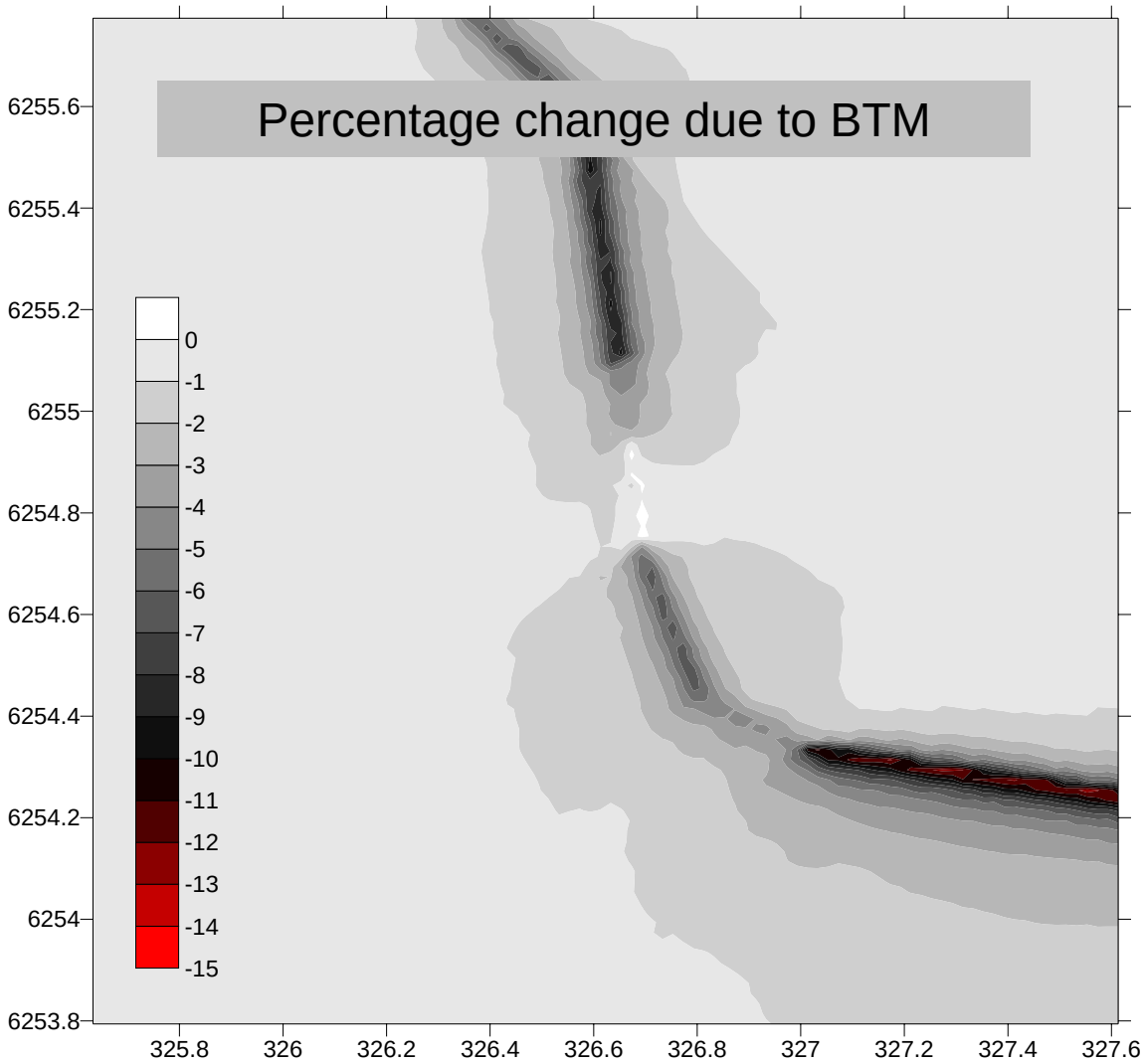


Local scale impacts (mortality)

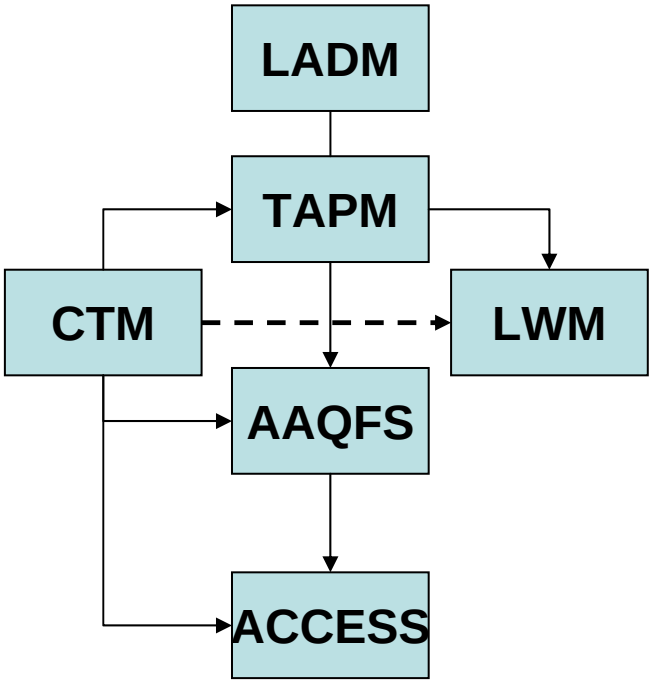
PM_{10} mortality contours (deaths/km^2/day)

$N = D_{C0}(C_{24} - C_t)P$
and,
$D_{C0} = P_0(RR-1)$

Where,
N = total increase in mortality
D_{C0} = increase in mortality over baseline per unit concentration
P_0 = baseline mortality
RR = residual risk (1.01 per 10µg/m^3)
P = Population
C_{24} = 24hr average PM_{10}
C_t = Threshold concentration



LWM SIMULATION
•Sydney (Victoria Rd)
•10m computational grid
•ITS vehicle link emissions
•MAQS inventory- other src's

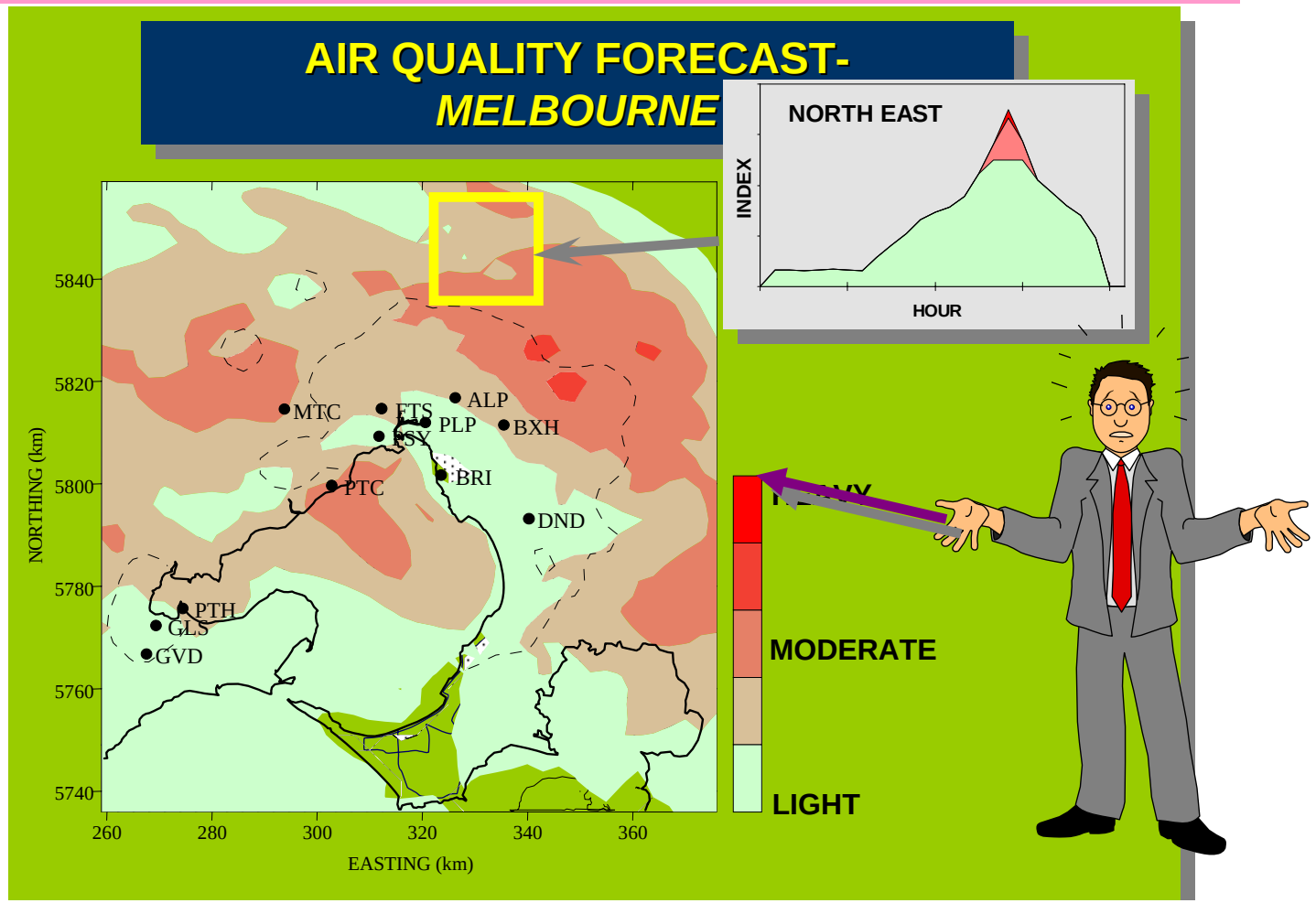


AAQFS

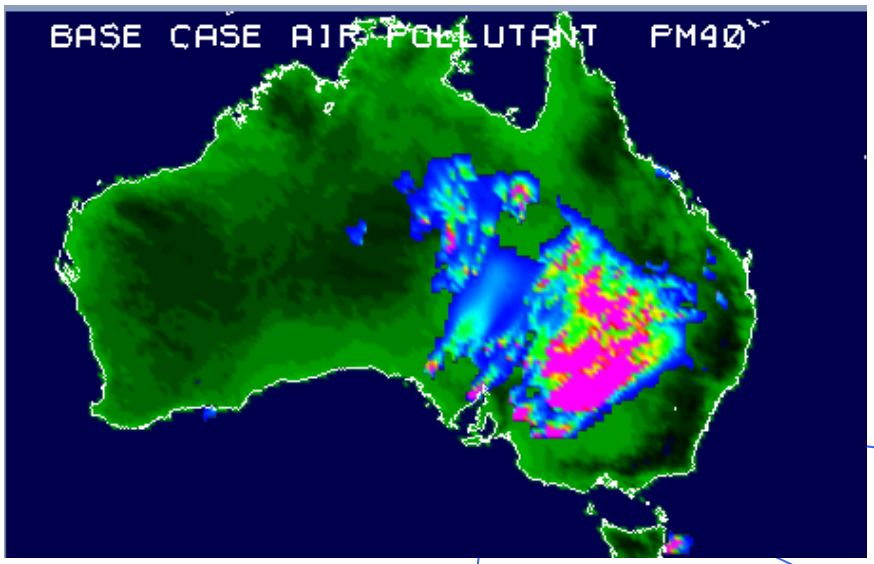
http://www.csiro.au/services/ps2o1.html

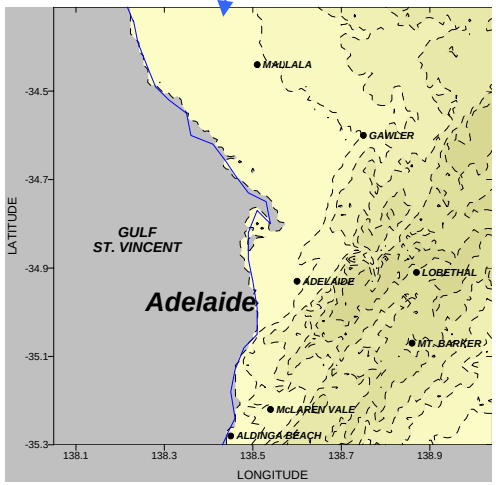
Prognostic forecasting for resolution, exceptional conditions

Tomorrow will be fine and sunny
-with moderate to heavy air pollution



Australian Air Quality Forecasting System





Regional and urban grids

- BoM's meso_LAPS (0.05°) nested in global NWP GASP

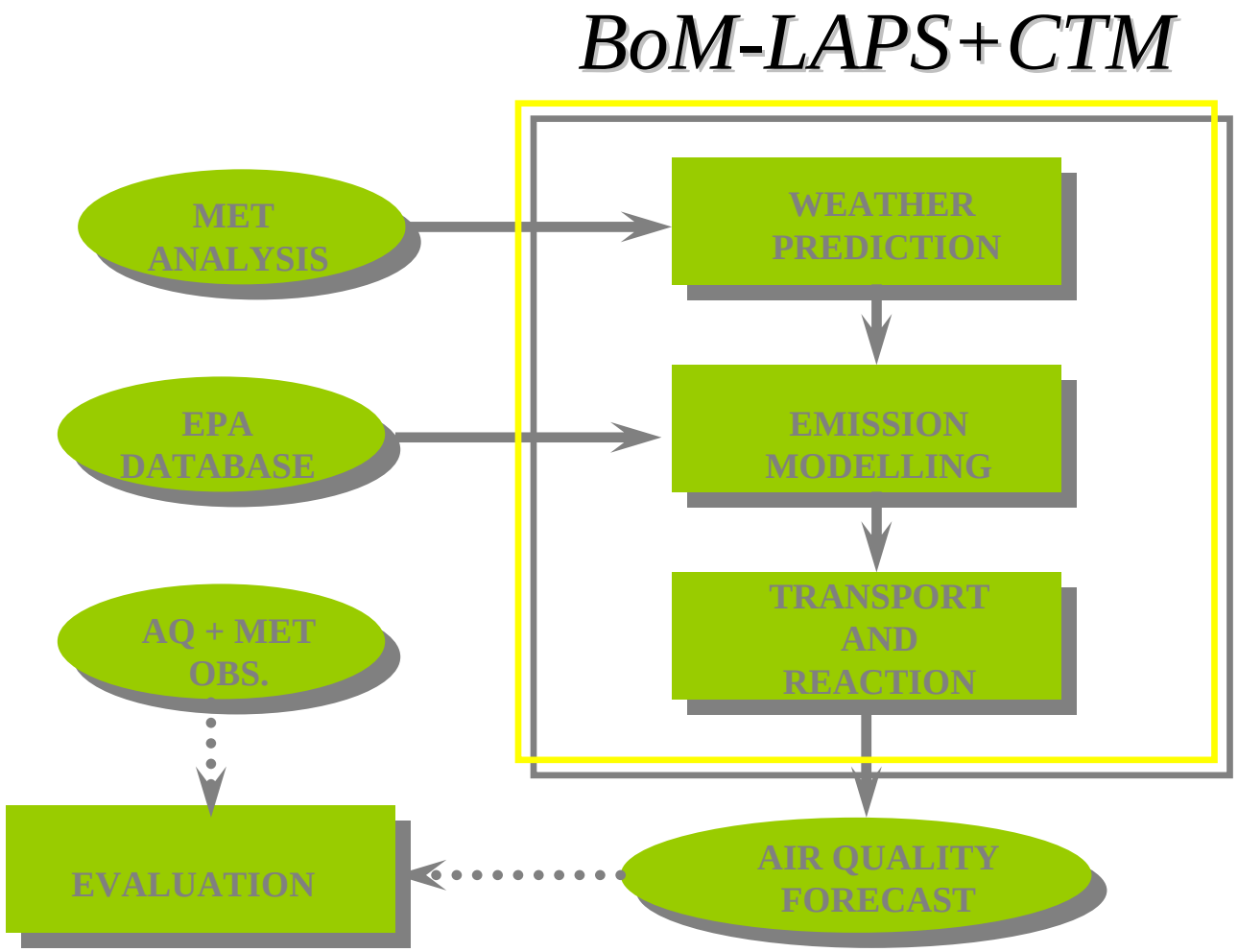
- CTM (0.05 and 0.01°);

- gas-phase primary and photochemical smog species;

- aerosol species include dust, sea salt, primary aerosols (domestic wood combustion, motor vehicle) + secondary (simple) inorganic.

- hourly 24-36 hour forecasts issued twice per day

The System Components



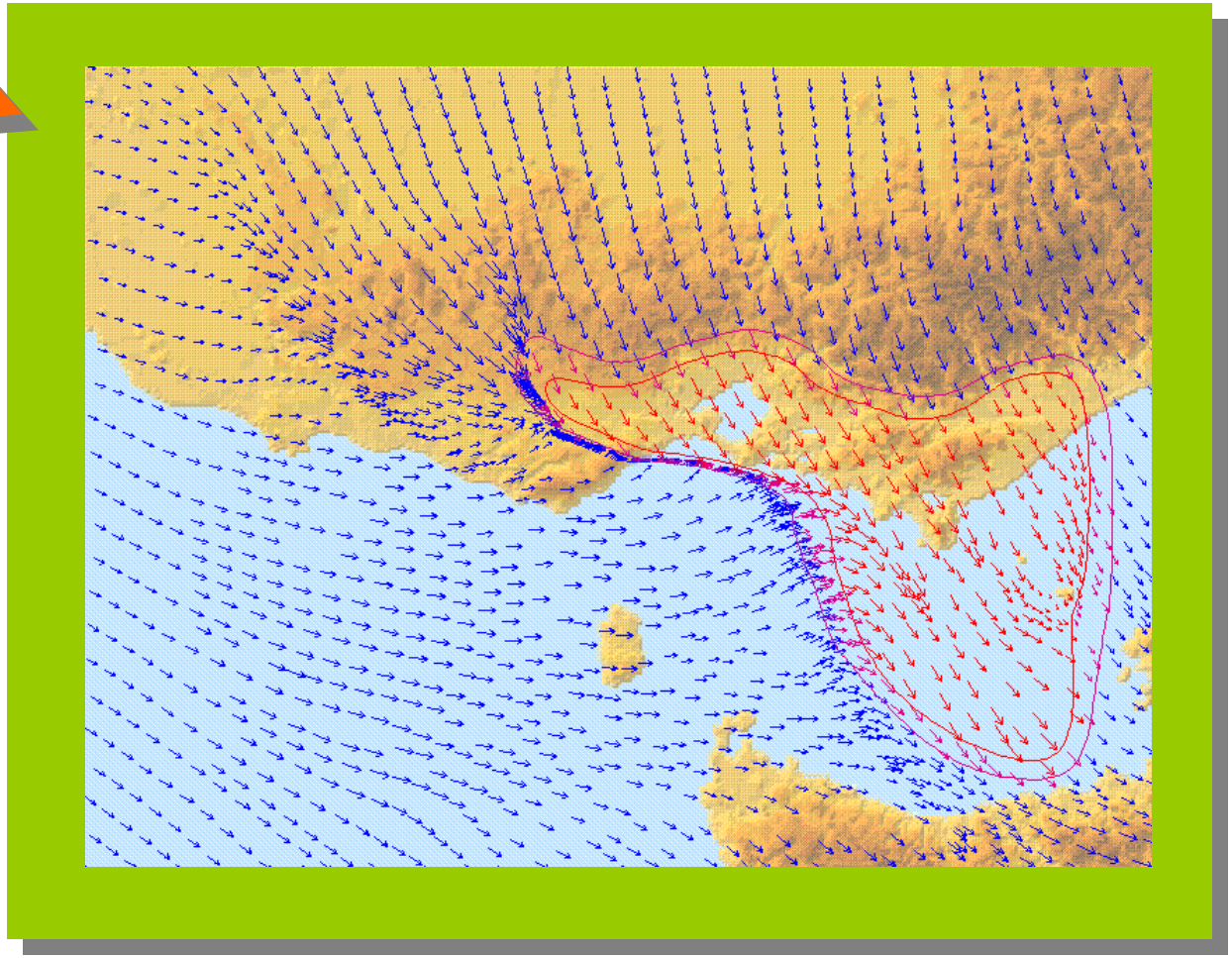
AAQFS Weather Model

WEATHER MODEL

EMISSIONS INVENTORY

AIR QUALITY MODEL

AIR QUALITY FORECAST



AAQFS Emissions Inventory

SOURCE CATEGORIES

WEATHER MODEL

EMISSIONS INVENTORY

AIR QUALITY MODEL

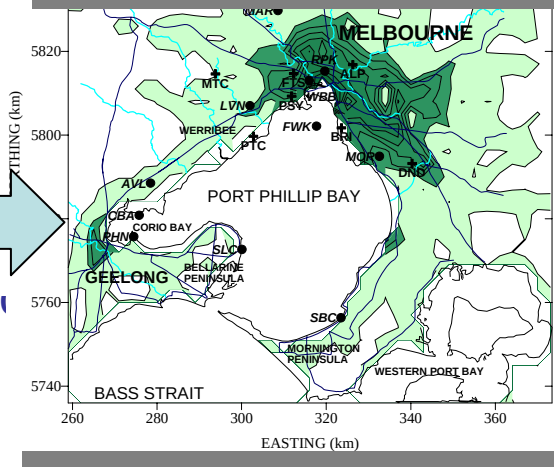
AIR QUALITY FORECAST

Vehicle fleet emissions dominate urban sources

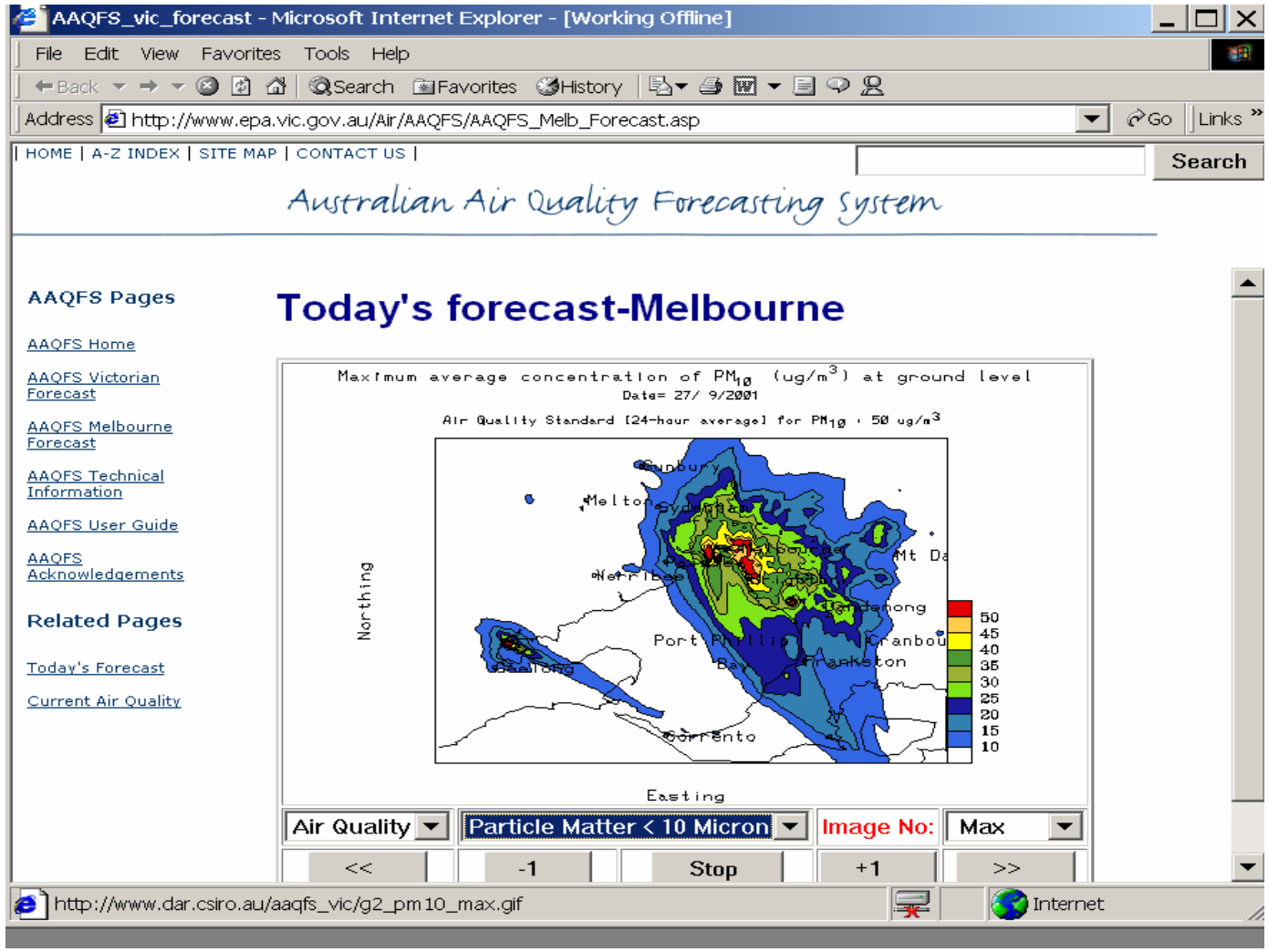
TAIL-PIPE EMISSIONS

ROAD-LEVEL EMISSIONS

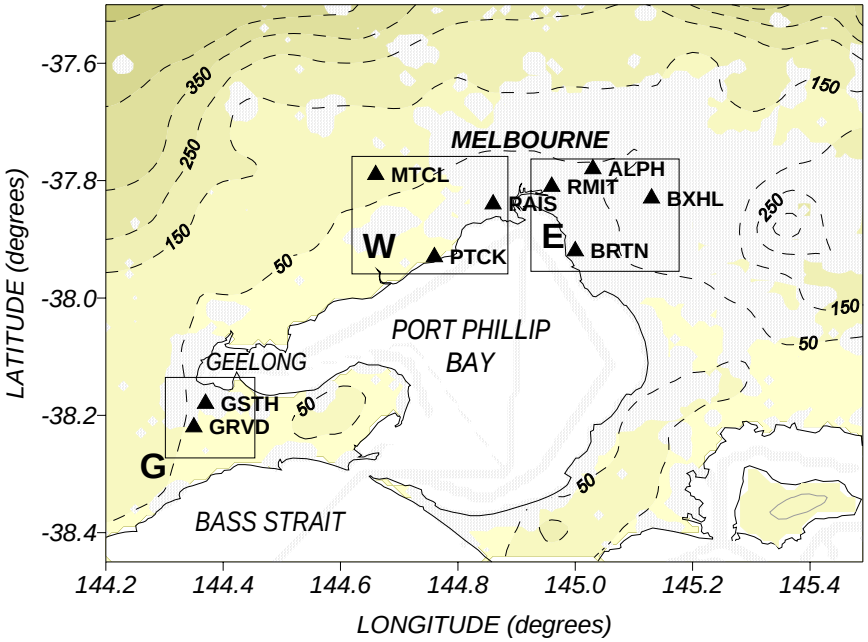
Fleet emissions - Melbourne

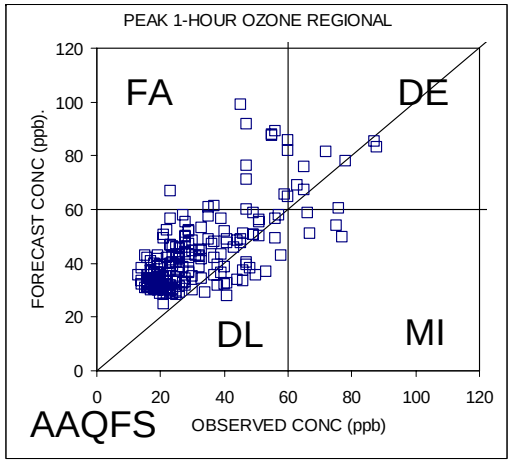


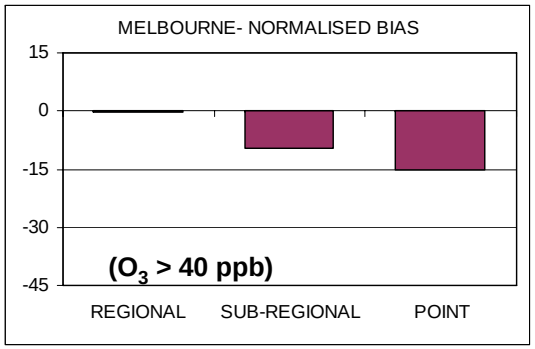
Melbourne forecasts on the Internet for public display

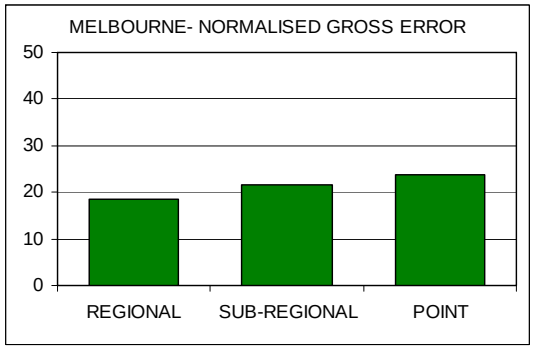


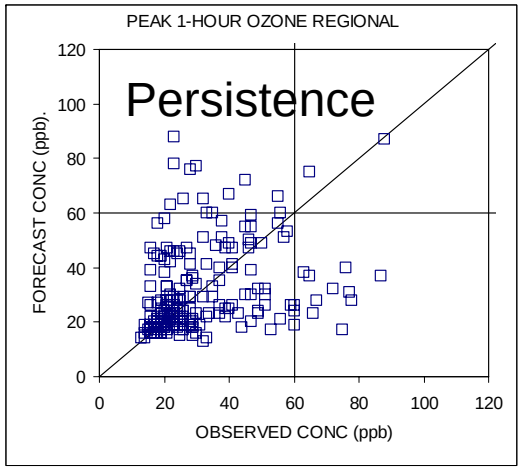
AAQFS forecasting performance: Melbourne daily peak 1-h ozone, 2 years





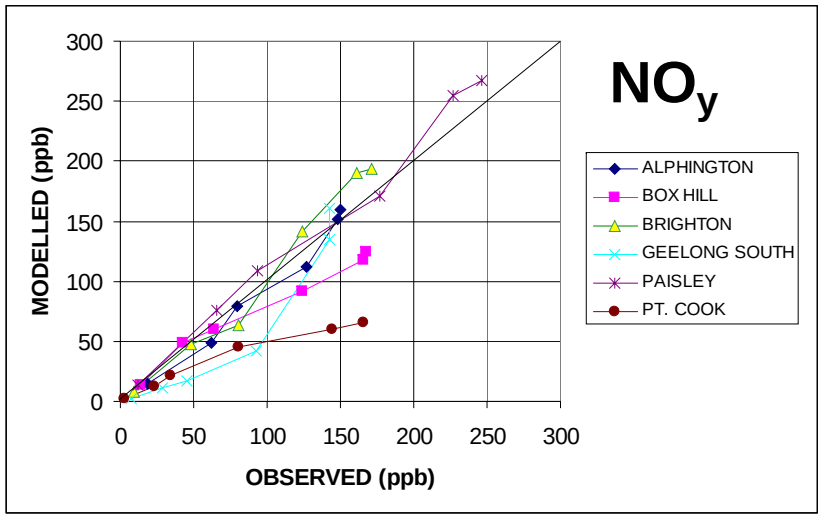


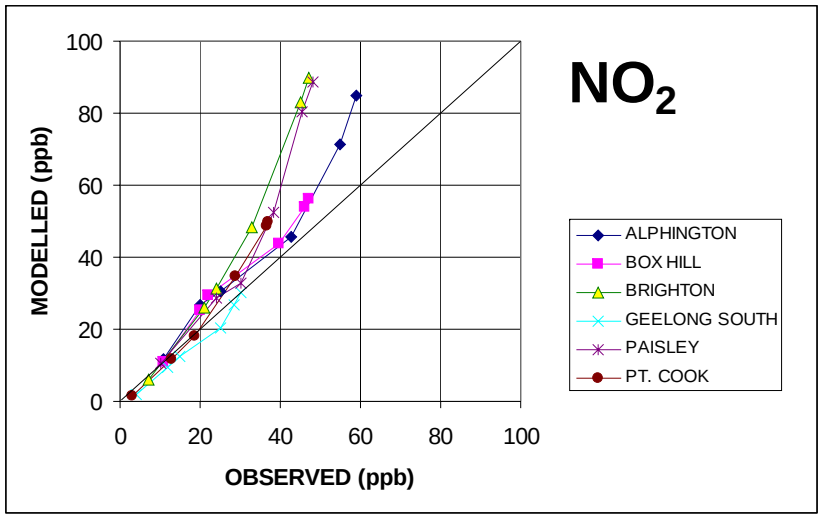


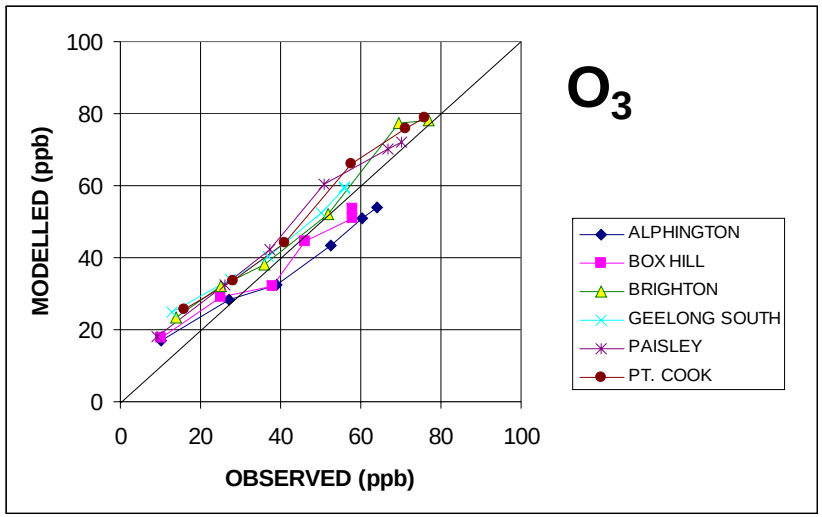


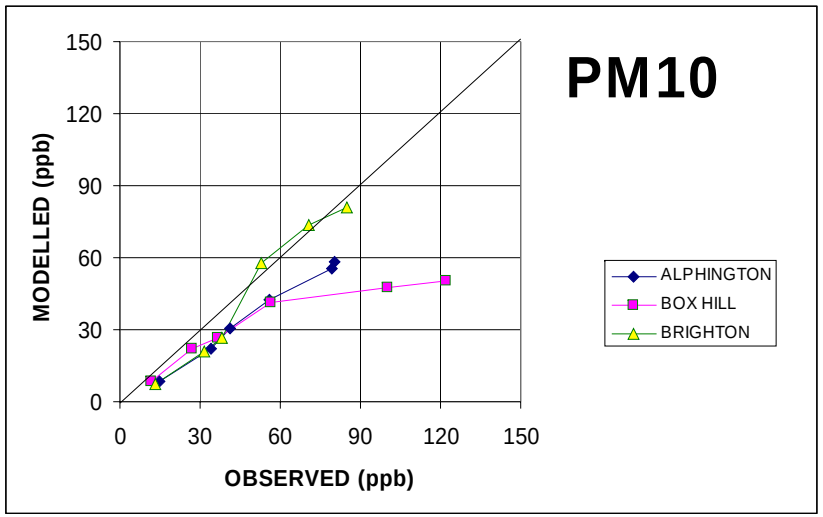
(Regional=entire grid; Sub-regional=G+W+E; Point=individual monitoring sites)

50^{th},90^{th},95^{th},99^{th},99.9^{th},100^{th} percentile



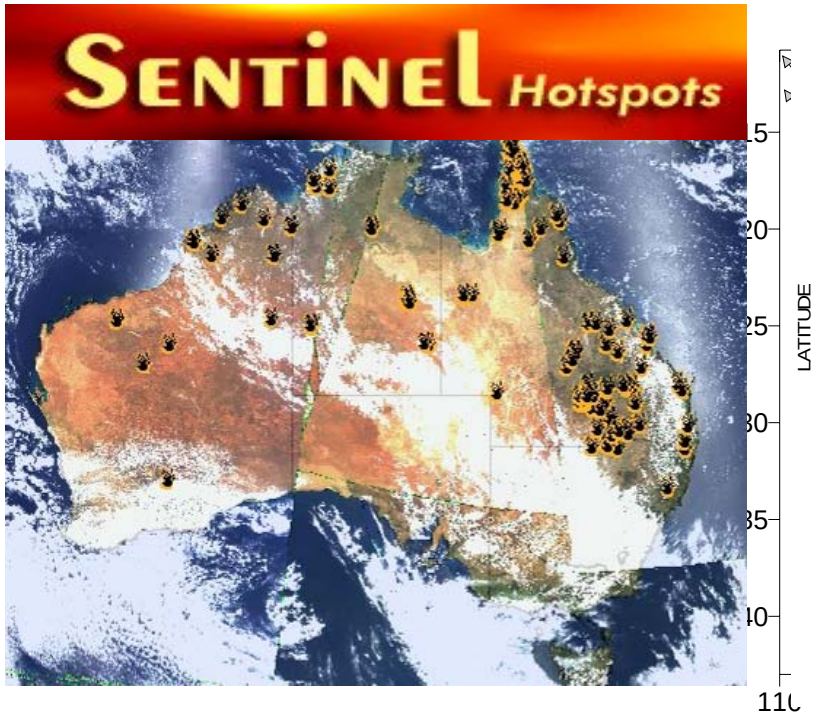


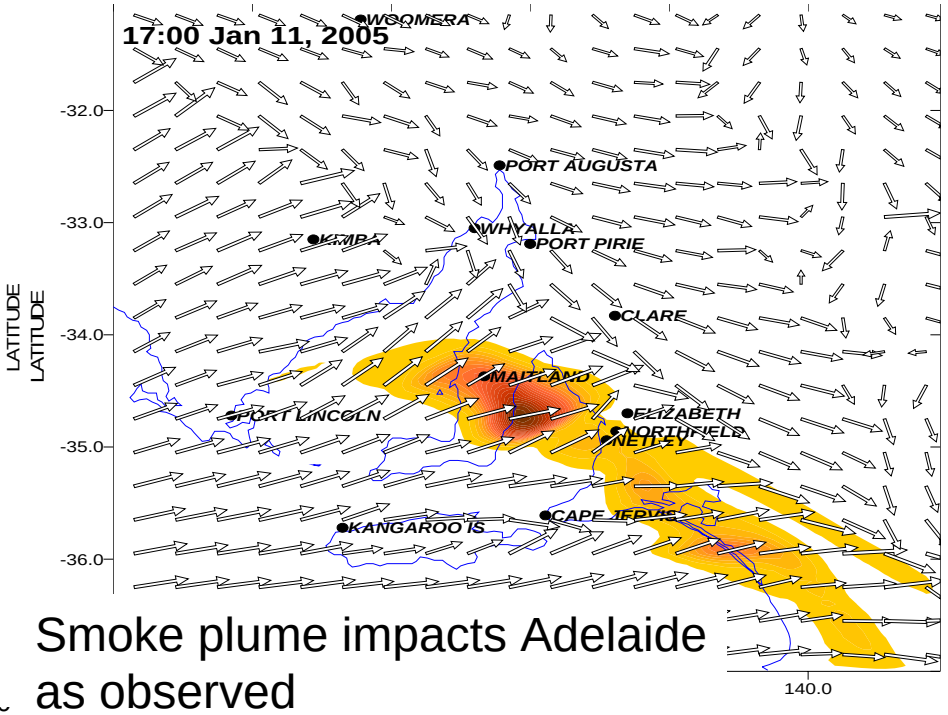




Smoke Plume Envelope Forecasting with AAQFS

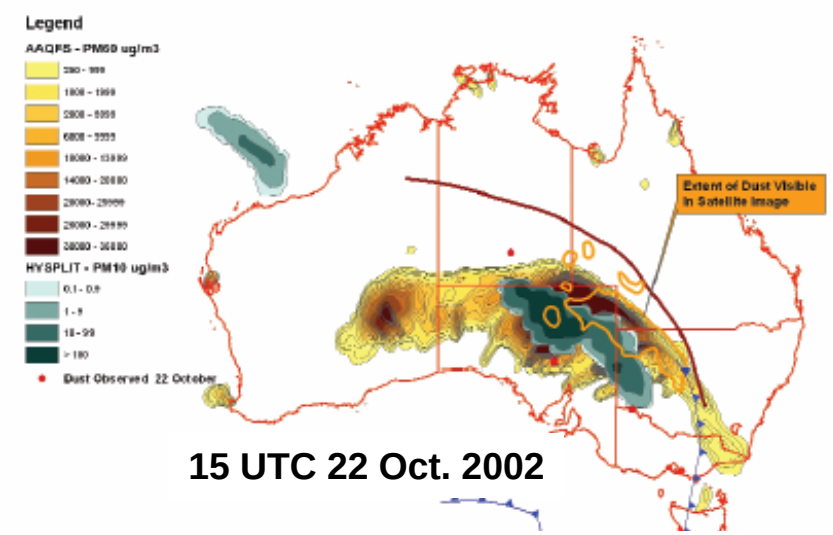
- Retrieve automated hotspot locations via satellite images
- Process the data to determine fire locations
- Initiate qualitative emissions at source locations and compute transport and dispersion as a passive scalar



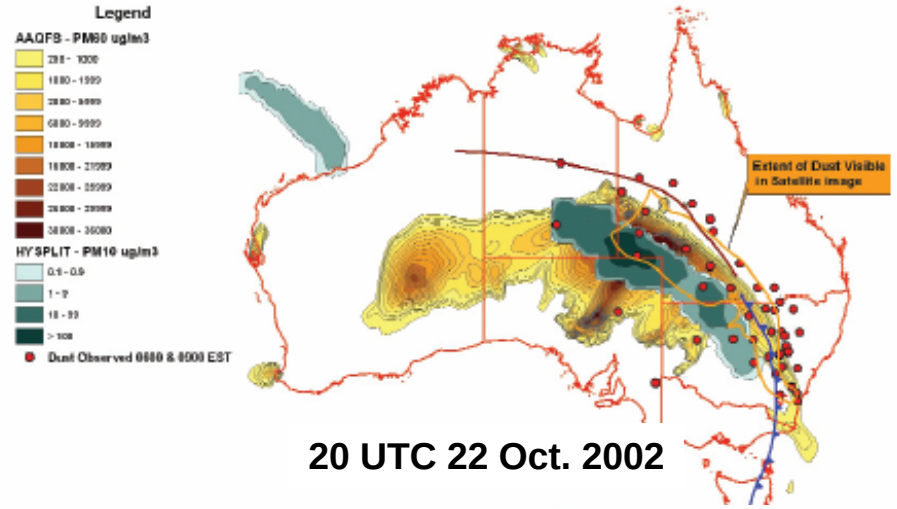


Smoke plume impacts Adelaide as observed

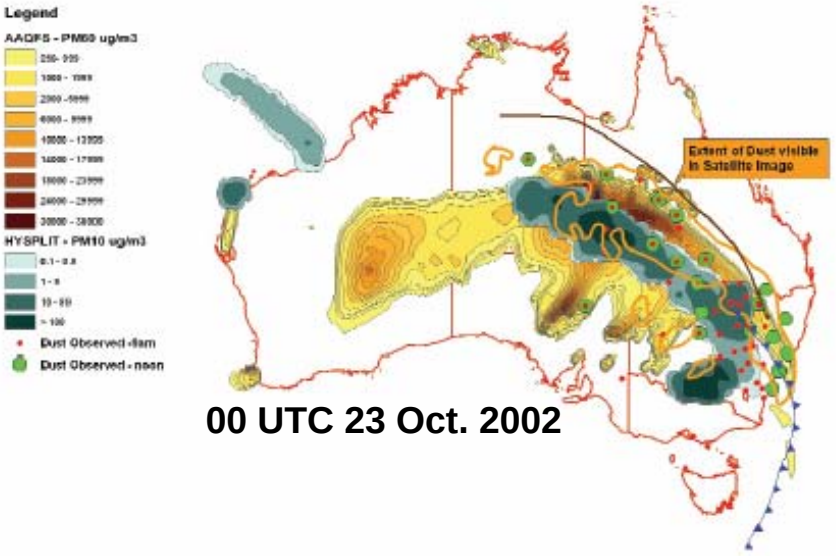
Forecasting Wind-Blown Dust with AAQFS



15 UTC 22 Oct. 2002



20 UTC 22 Oct. 2002



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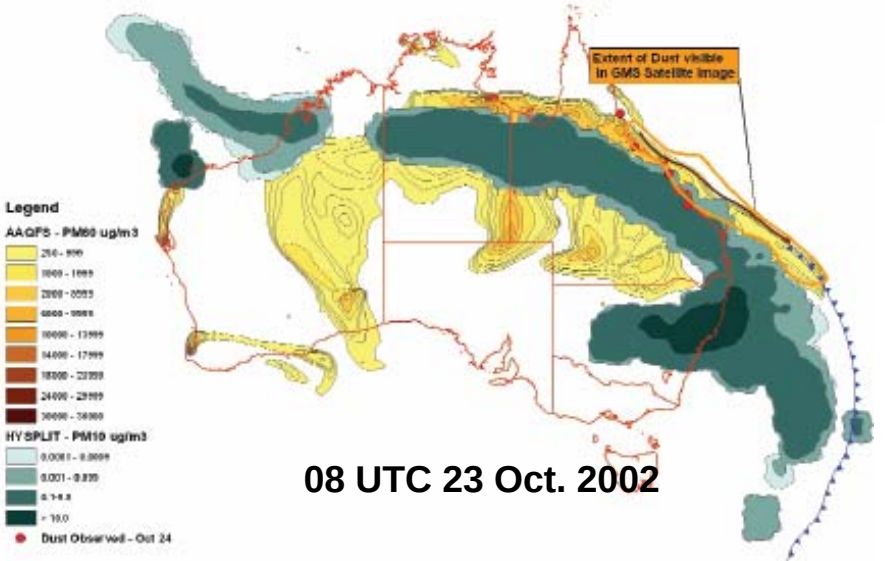
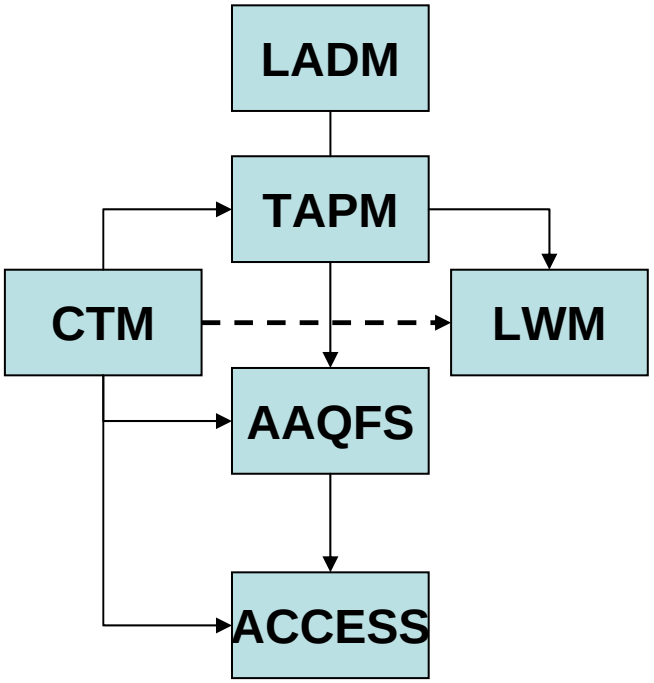


08 UTC 23 Oct. 2002



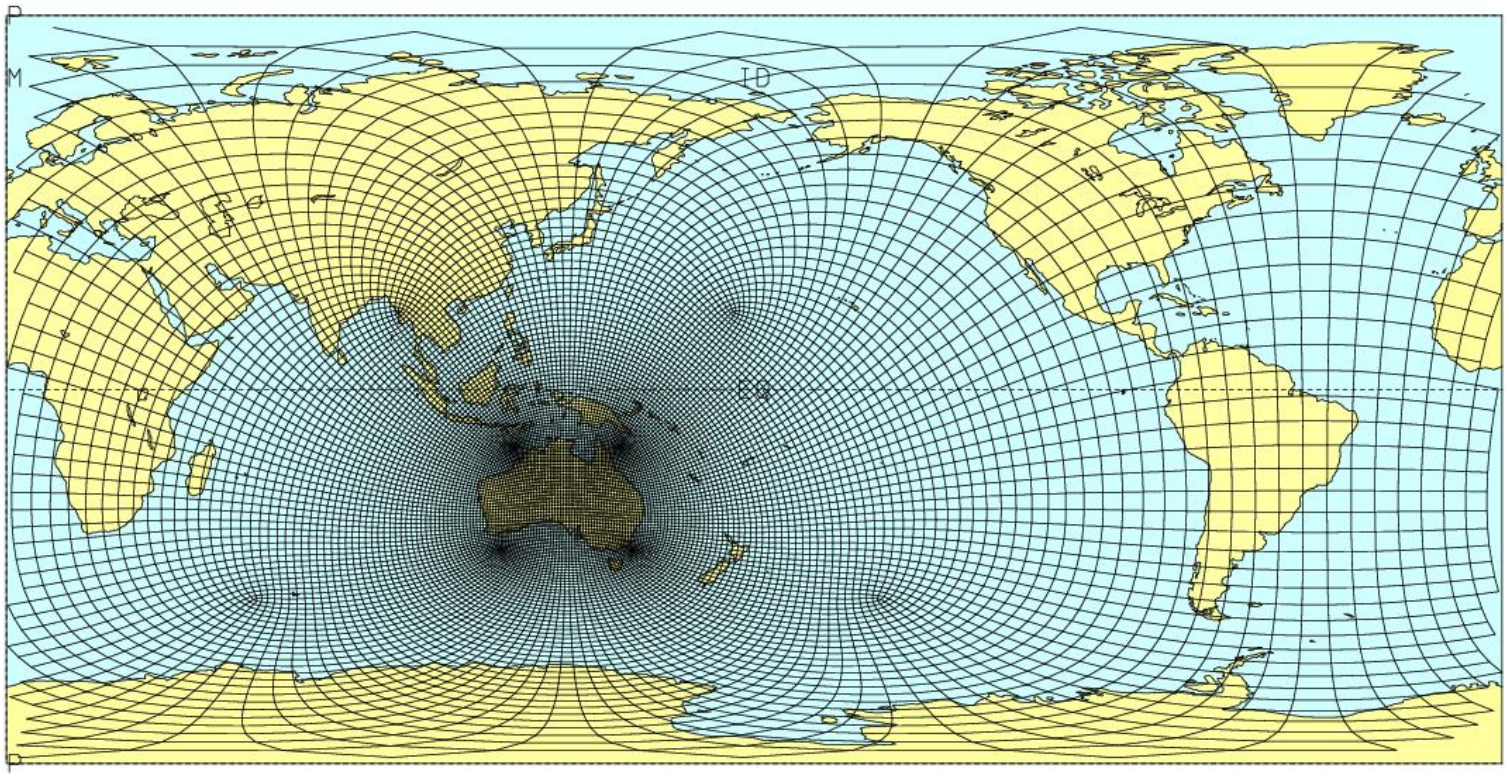
CCAM + TAPM

CSIRO

www.csiro.au

CCAM set up for Australia

To achieve high resolution over any selected location,
the first panel of the cube is shifted over that location,
then the Schmidt transformation is applied to map to sphere
- preserves orthogonality and isotropy



Resolution over Australia is about 60 km, with Schmidt factor = 0.3

Features of CCAM dynamics

2-time-level semi-Lagrangian, semi-implicit

total-variation-diminishing vertical advection

reversible staggering

- ❖ has very good dispersion properties

selective off-centring in time (to avoid semi-Lagrangian mountain resonances)

- ❖ leads to better tropical rainfall

***a posteriori* conservation of mass and moisture**

Schmidt transformation used for zooming

non-hydrostatic version now available

•denotes only feasible in C-CAM and some grid-point models

•denotes also possible for spectral models

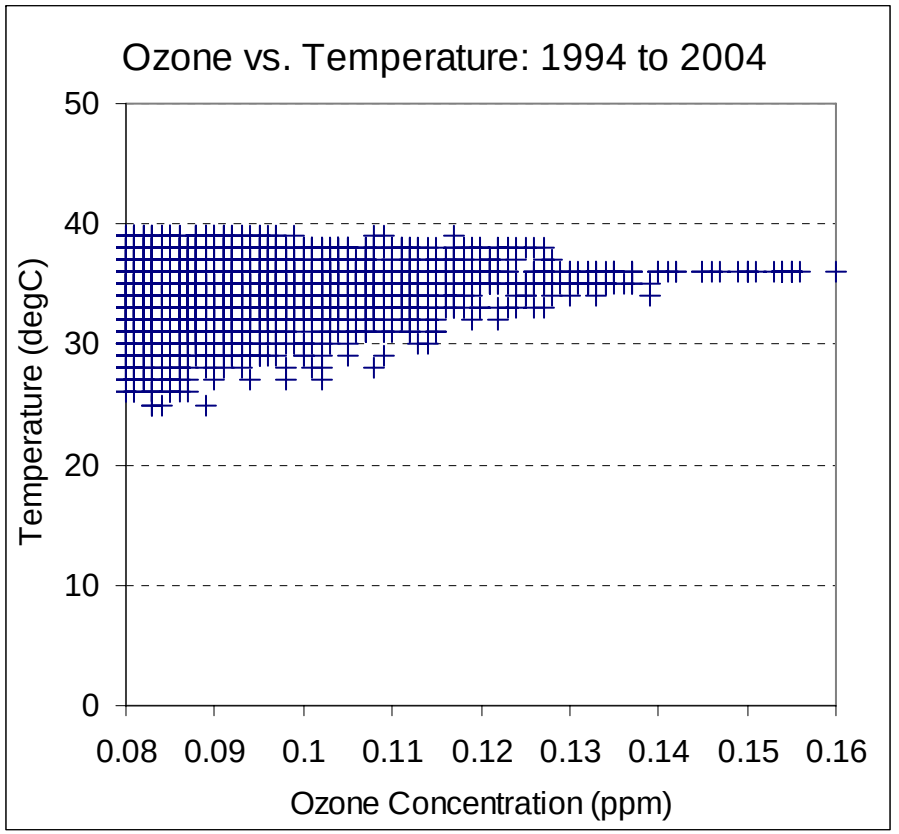
Expected Changes in urban ozone

In Sydney, currently 15 days per year above 30^{o}C. Predicted to be between 18–31 days by 2030, 22–117 days by 2070.

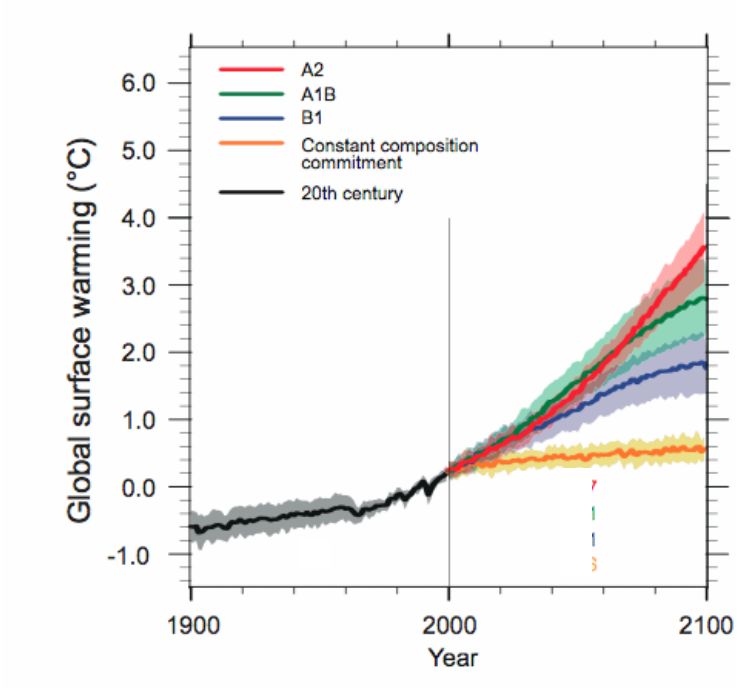
Ozone formation increases with temperature.

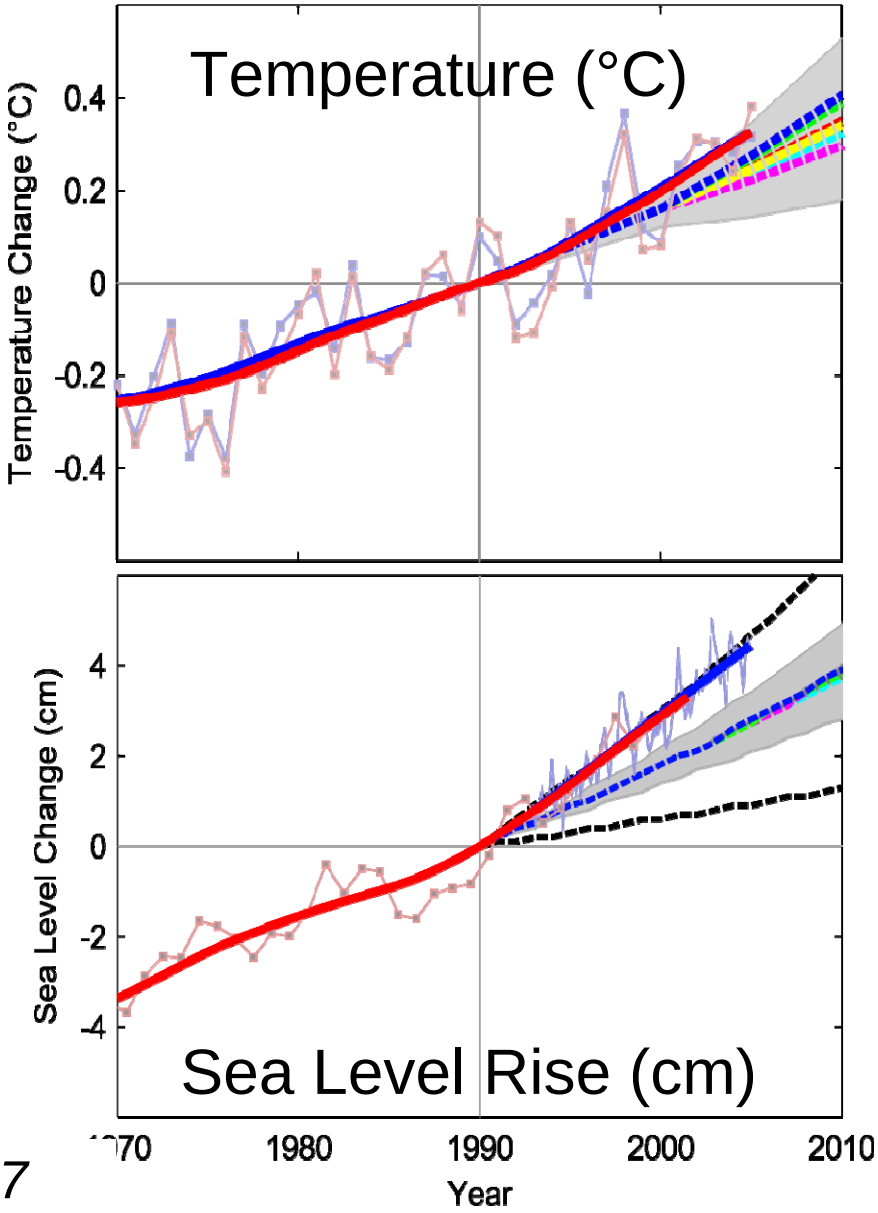
Secondary aerosol production will increase

Dispersion meteorology is likely to change



We are tracking the higher emissions scenarios – A2 is very reasonable



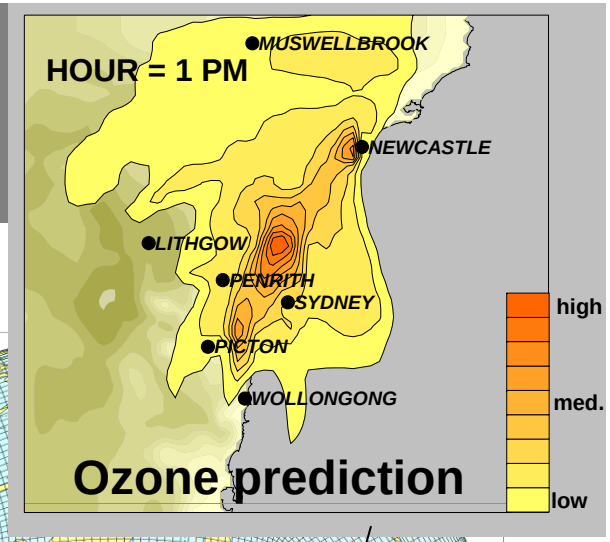


SRES Emission Scenarios:

A "family" of future emission trajectories, for a range of economic, technologic and society futures

Rahmsdorf et al. 2007

Approach (current)



Compare ozone levels for 3 decades: 1996–2005, 2021–2030, 2051–2060.

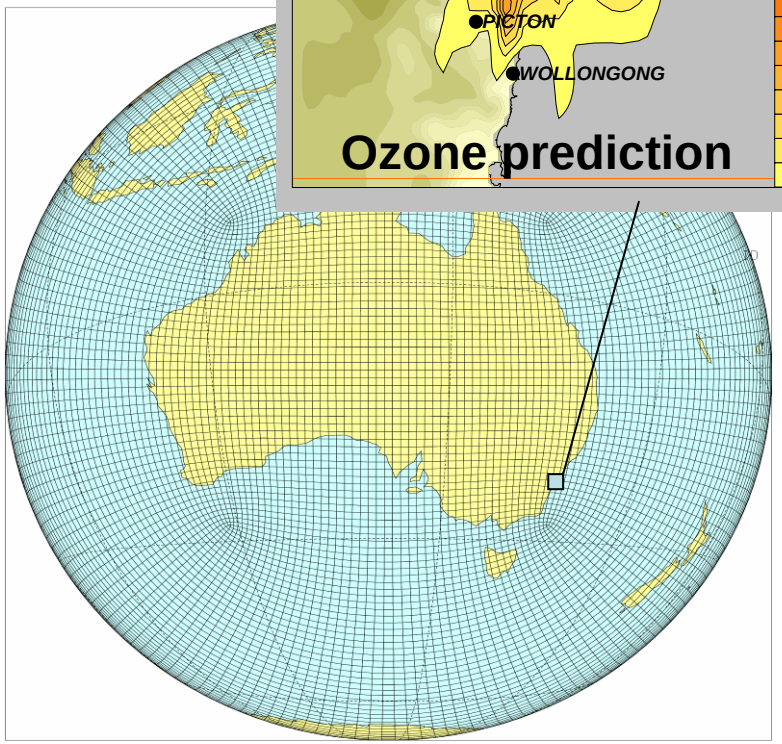
Nest TAPM-CTM (grid spacing 3 km) into CCAM regional simulations for these periods

Eg for Sydney, could calculate a relative risk (of ?) for O_3>30 ppb:

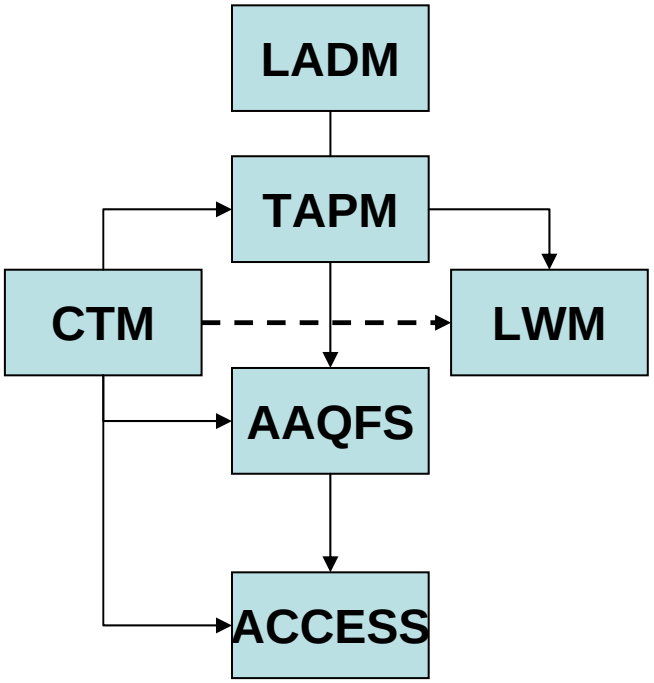
1996–2005: 0.65%

2021–2030: 0.78% ie +20%

2051–2060: 1.04% ie +50%



CCAM grid- effective resolution of 70 km over Australia

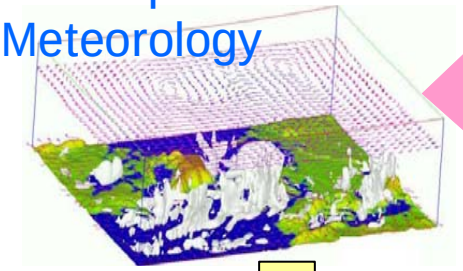


Model Improvements

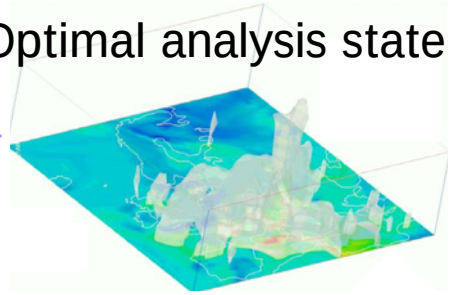
www.csiro.au

Model Improvement – ongoing

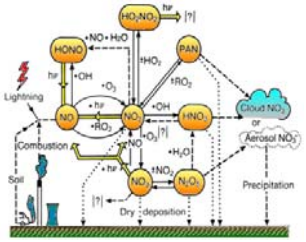
Transport Meteorology



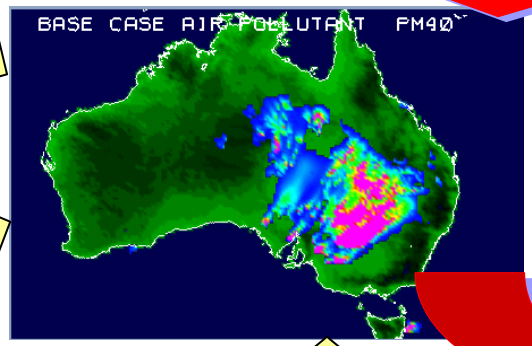
Optimal analysis state



Chemical kinetics

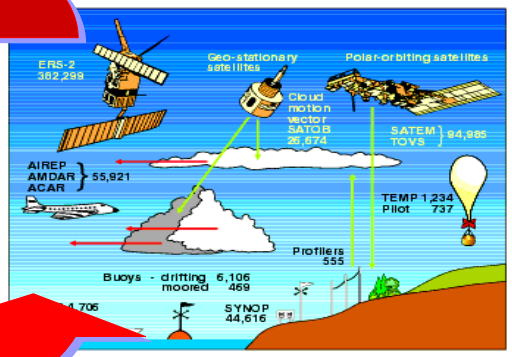


CTM

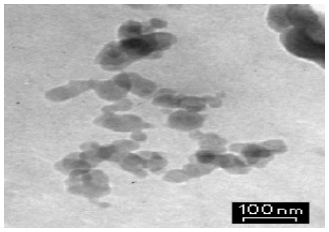


Data Assimilation

Observations



Aerosols



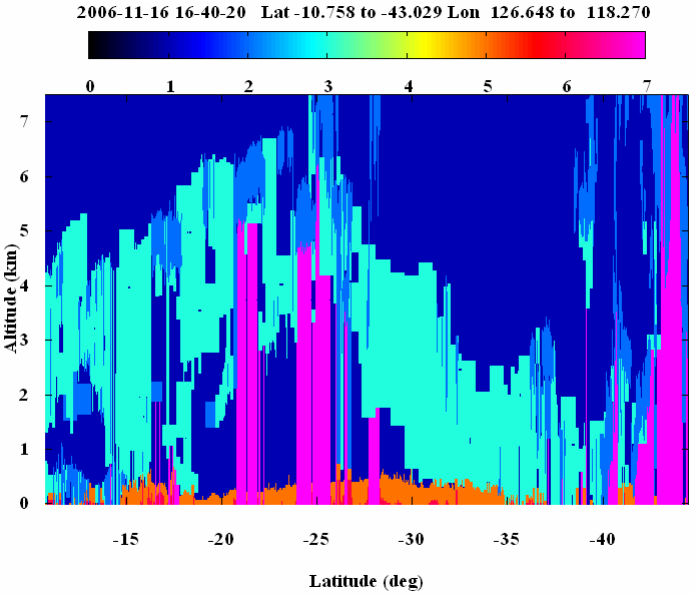
Emissions

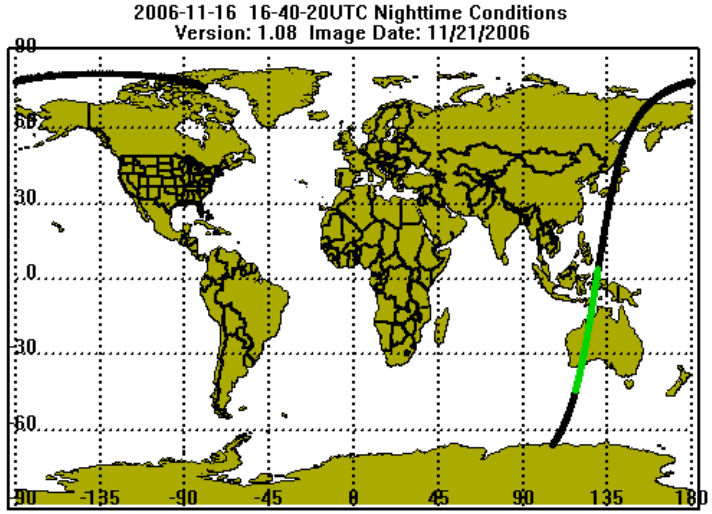
Improved:

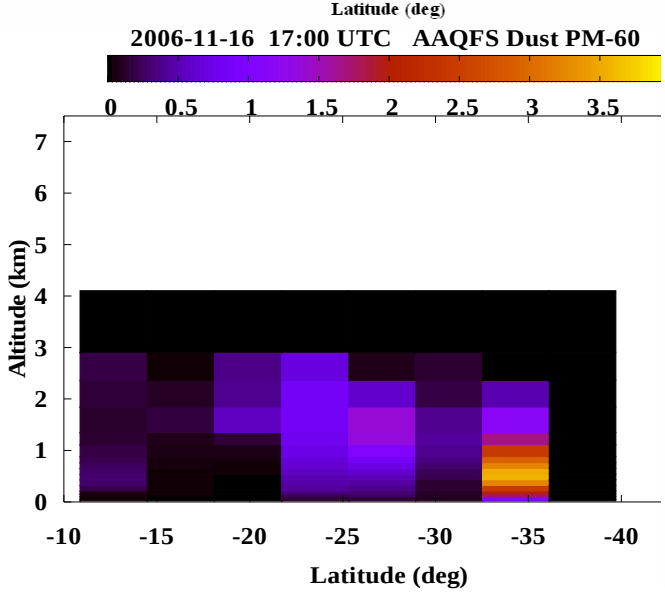
- forecasts
- science
- field experiment design
- models
- emission estimates
- S/R relationships

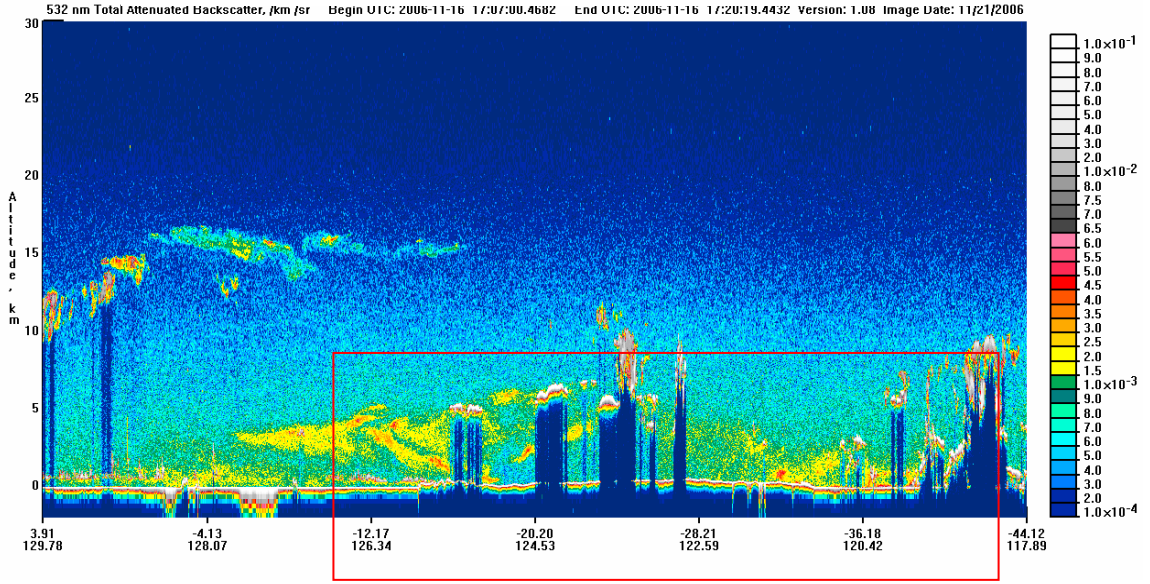
after Greg Carmichael 2007

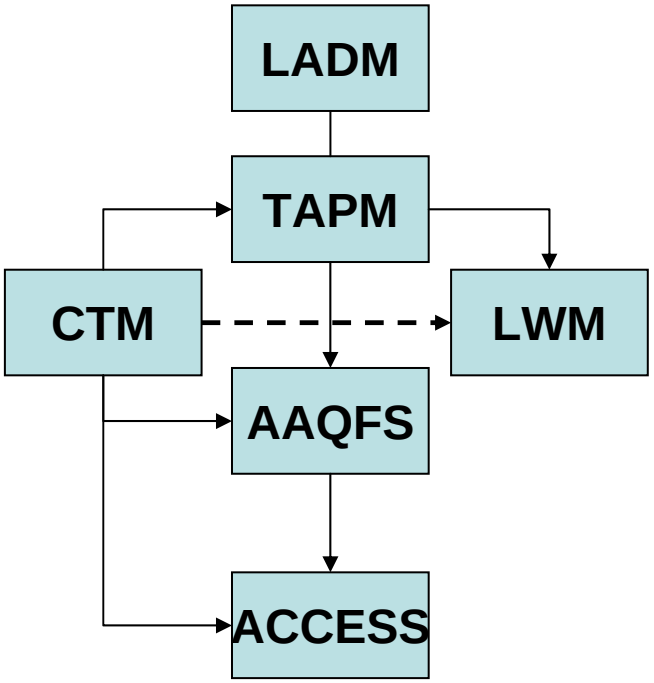
AAQFS Validation with CALIPSO











ACCESS – a unified future

CSIRO

www.csiro.au

http://www.dar.csiro.au/access/

Objectives of ACCESS

ACCESS

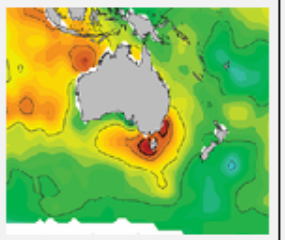
The Australian Community Climate Earth–System Simulator

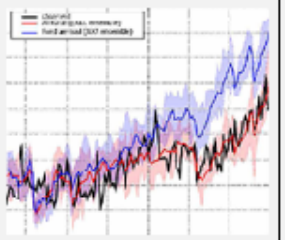
Steering Committee
Science Advisory Group
Teams
Atmospheric Modelling Team
Ocean Modelling Tea

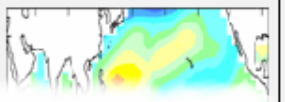
OBJECTIVES OF ACCESS

The Australian Community Climate Earth-System Simulator (ACCESS) is a coupled climate and earth system simulator to be developed as a joint initiative of the Bureau of Meteorology and CSIRO in cooperation with the university community in Australia.

The key objectives of ACCESS are to create models and modelling outcomes that:





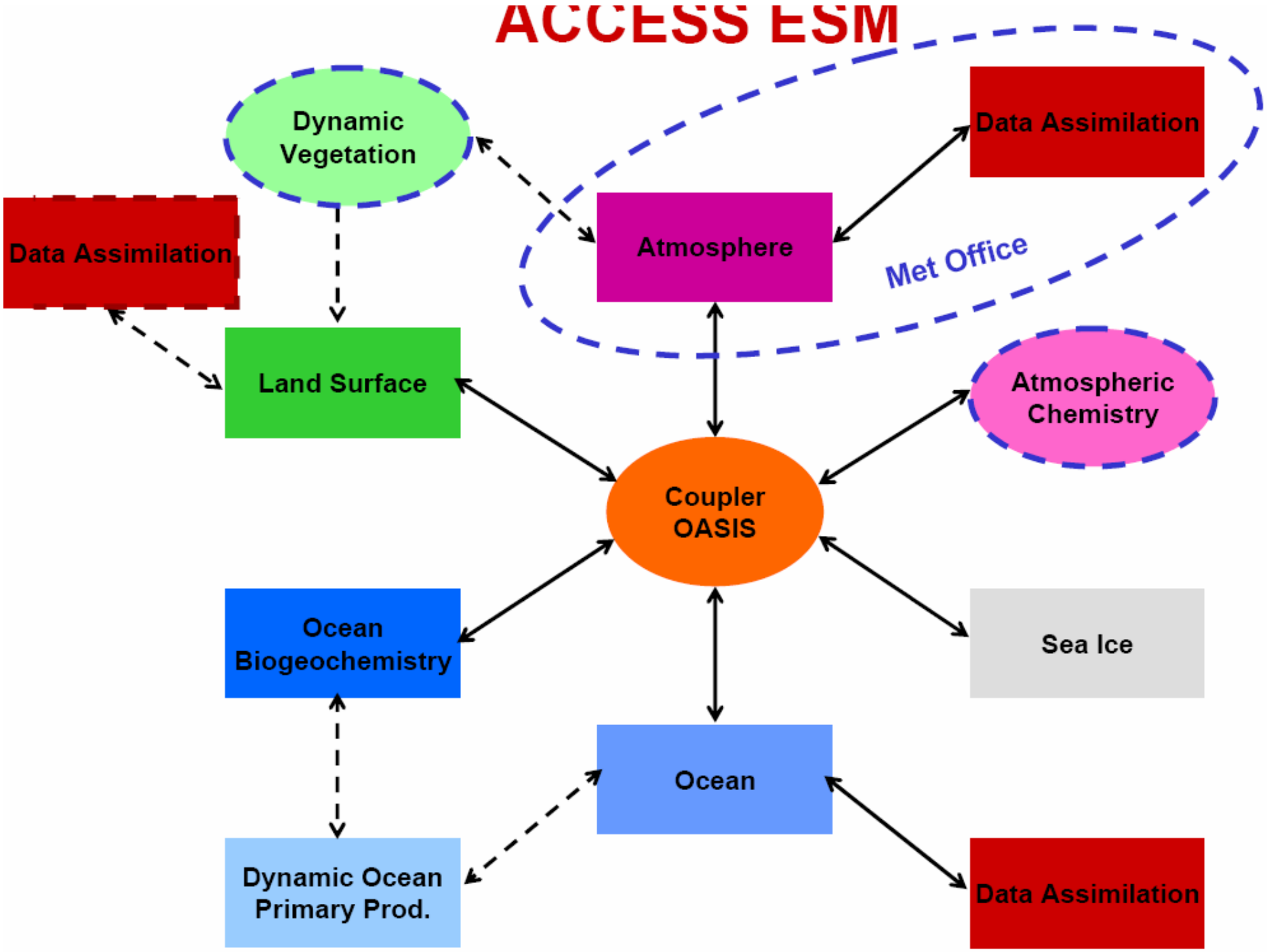


PARTNERSHIP

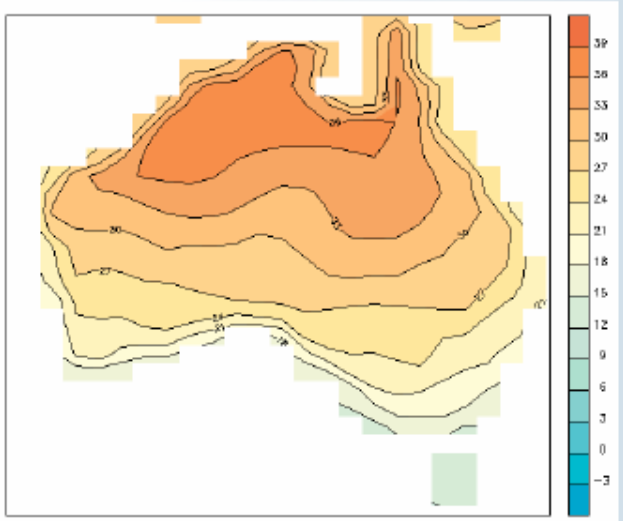
Australian Government
Bureau of Meteorology

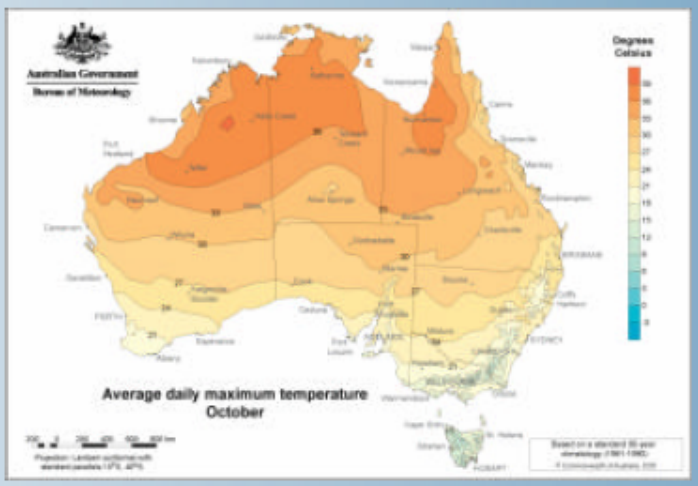
CSIRO

ARCNESS

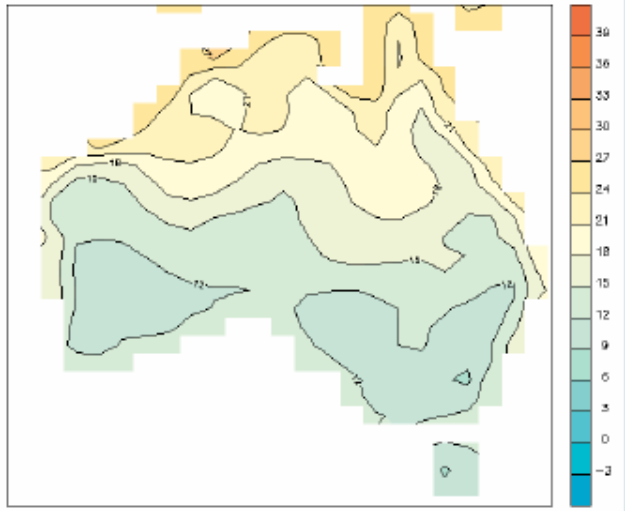

ACCESS ESM
Dynamic Vegetation
Data Assimilation
Data Assimilation
Atmosphere
Met Office
Land Surface
Atmospheric Chemistry
Coupler OASIS
Ocean Biogeochemistry
Sea Ice
Ocean
Dynamic Ocean Primary Prod.
Data Assimilation

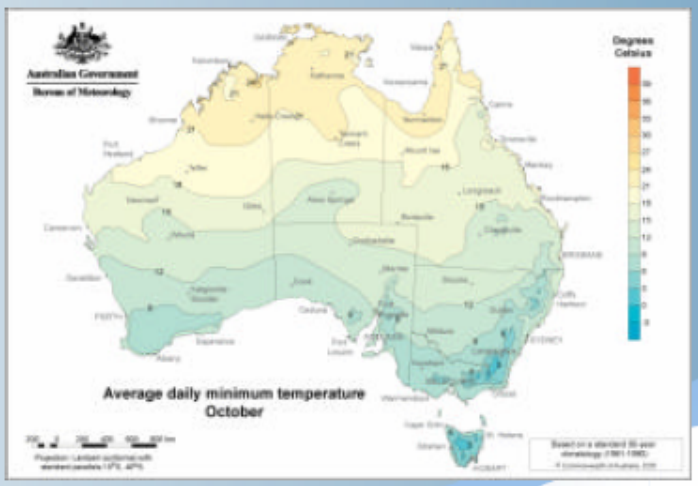
First Climate run with ACCESS/UM





T_{max}





T_{min}

ACCESS

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Thank You

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