Modelling Smoke Dispersion in the Bureau of Meteorology

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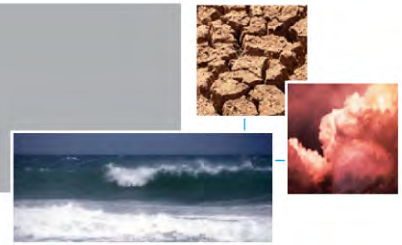
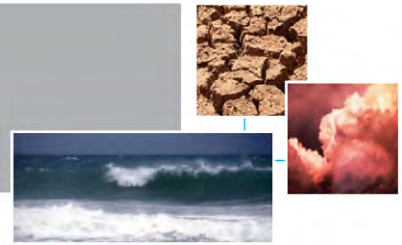
Outline



- What do we call “modelling smoke dispersion”?
- Why the Bureau?
- Background and summary of our experimental smoke dispersion system
- Limitations and future directions

Smoke Dispersion

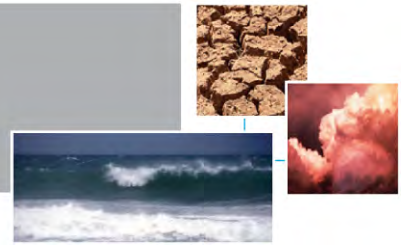


Once a blob of smoke leaves a fire, it :

- rises with the heat from the fire
- is transported away from a fire location by the wind (along with other gases and particulates)

  and
- is diluted over time through mixing with the air surrounding the smoke plume.

Smoke Dispersion



These latter two processes occur simultaneously, and are determined by the wind and temperature of the atmosphere

So to predict the transport and dispersion, we need to know forecast

Wind

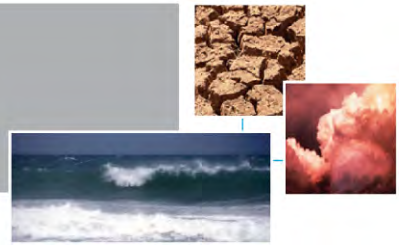
Temperature

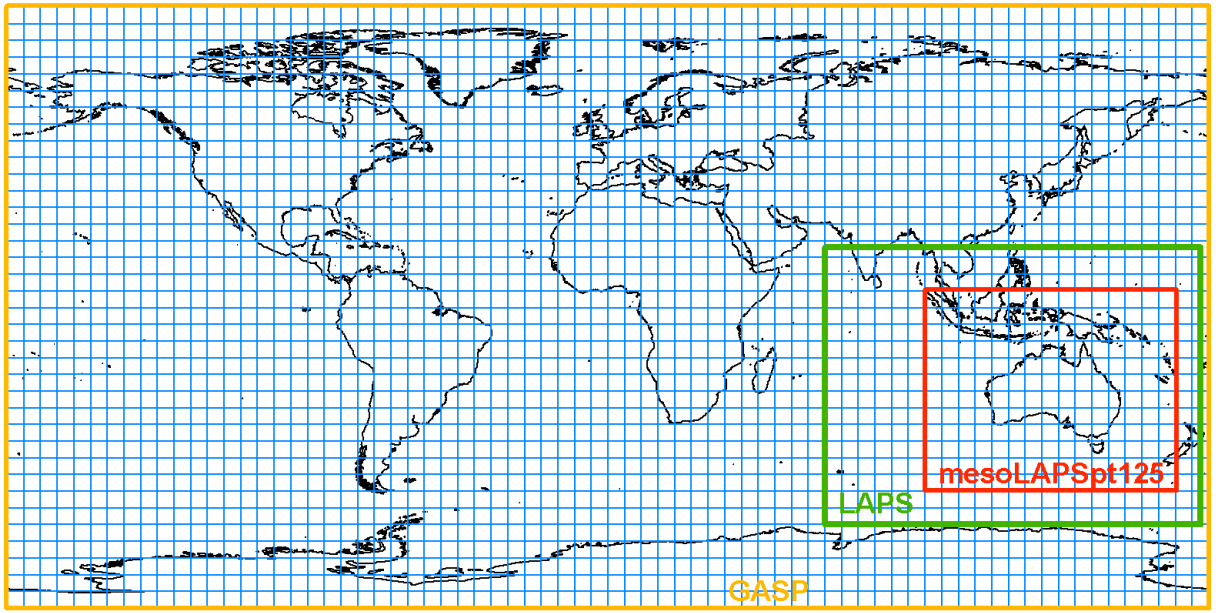
Humidity

Turbulence

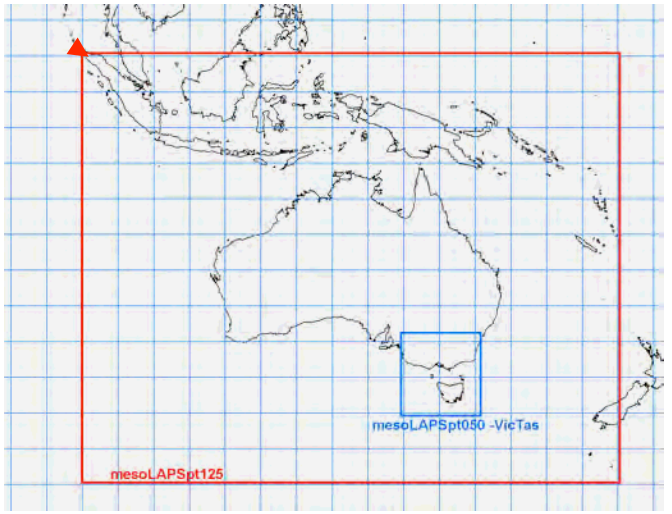
at multiple levels, times, and as close as possible in space

That's where the Bureau comes in!





- **The Bureau runs a suite of Numerical Weather Prediction (NWP) models on a range of scales from global to 5km 2-4 times per day**
  - **GASP - global model**
  - **LAPS - regional model**
  - **mesoLAPS_pt125 -Australia**
  - **mesoLAPS_pt05 – capital cities & surrounds**



- **The variables required to calculate dispersion are already produced by the models**

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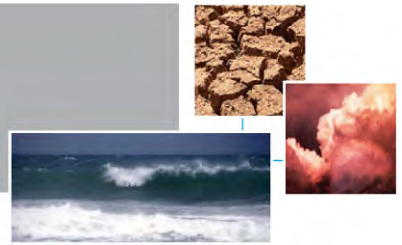
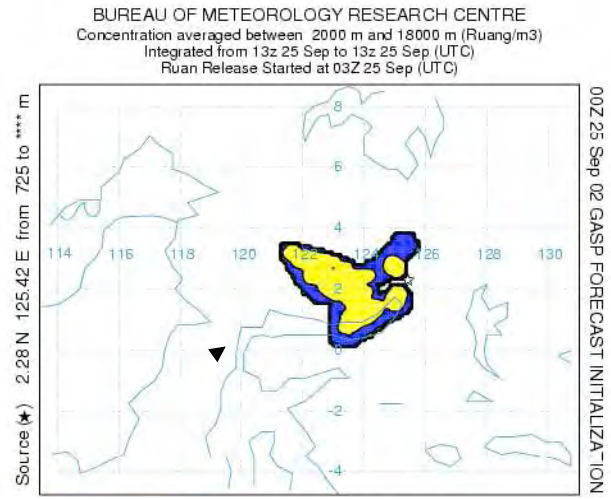
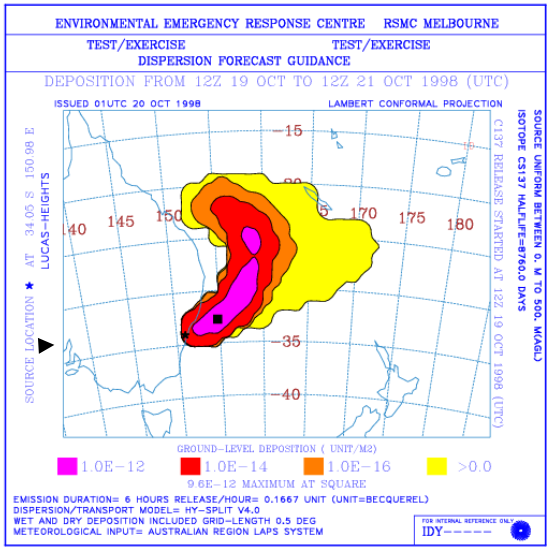
As well



The Bureau is a Regional Specialised Meteorological Centre for Environmental Emergency Response (EER) and so is responsible for the production of transport and dispersion forecasts for a range of emergencies such as:

- Foot & Mouth outbreaks
  - Advice to Agriculture & Heath Authorities
- Volcanic Eruptions
  - Ash forecasts for aircraft
- Nuclear Accidents





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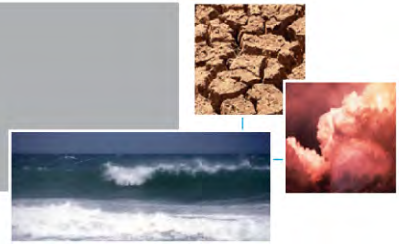
so .....

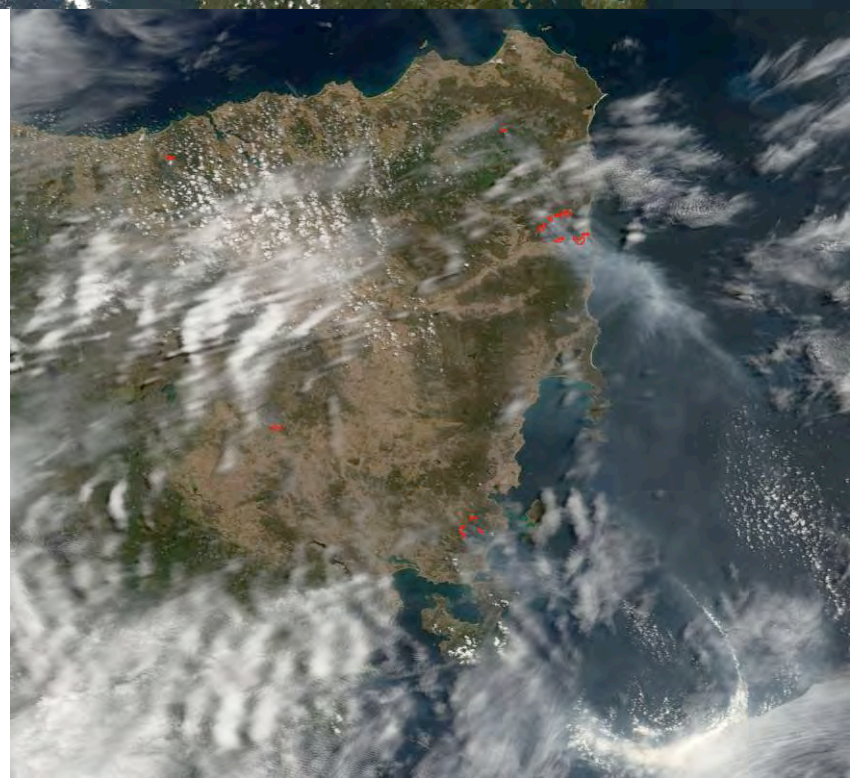


- **Smoke transport modelling is a logical extension of the Bureau's existing capabilities.**

- **The Bureau also has long-established relationships with fire agencies**
- **These led to an AFAC > Bushfire CRC > Agency-funded experimental system**

Why it is what it is:

- Designed as a decision support tool for land managers (eg.Parks Tas. FT)
- Has evolved with input from land management agencies to meet the agency's needs
- Ongoing development to take advantage of evolving technology
- Developed for prescribed burning but has uses for bushfires also.



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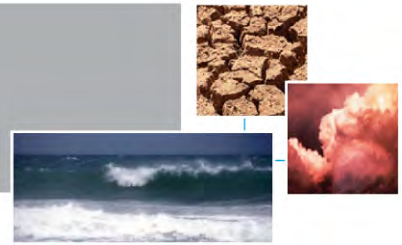
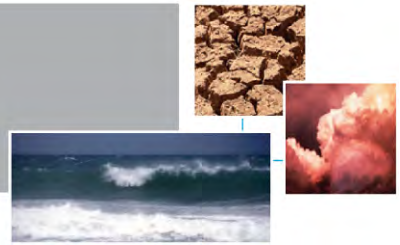
Routine Smoke Dispersion forecasts



- National program
- Forecasts issued from fixed sites in each state
- Range of emissions times
- Standard plume rise (refined with time)
- Two sets of forecasts per day – AM/PM
  schedule determined by land manager's needs and Bureau operations
- "Standard" unit of emissions
- Products delivered via web

Design constraints



Meteorology

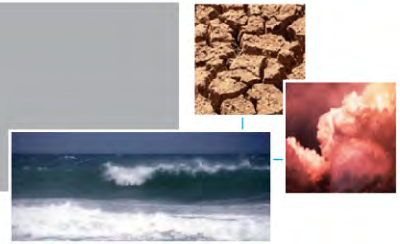
- *Use of operational numerical models (limits on computer resources) limits spatial resolution*

Additional inputs required for calculation of “actual” smoke concentrations

- *How much fuel is to be burned*
- *Moisture content of the fuel*
- *The amount of “pre-existing smoke”*
- *Heat Release -> Plume rise*

All have considerable uncertainty

Product delivery – first page



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Smoke Dispersion Forecasts

SMOKE FORECASTING

NSW | N.T. | Qld | S.A. | Tas | Vic | W.A. | Training

Home >>

Smoke Dispersion Forecasting

Congratulations on finding your way to the new look Smoke Dispersion forecast pages

News

- THe operational dispersion model, HYSPLIT, is being upgraded to version 4.9. This will allow the implementation of several advancements in source definition.
- During 2009 the Bureau's NWP mesoLAPS model will be replaced with a new model known as ACCESS. Ultimately this should allow the use of higher resolution meteorology.

Navigation

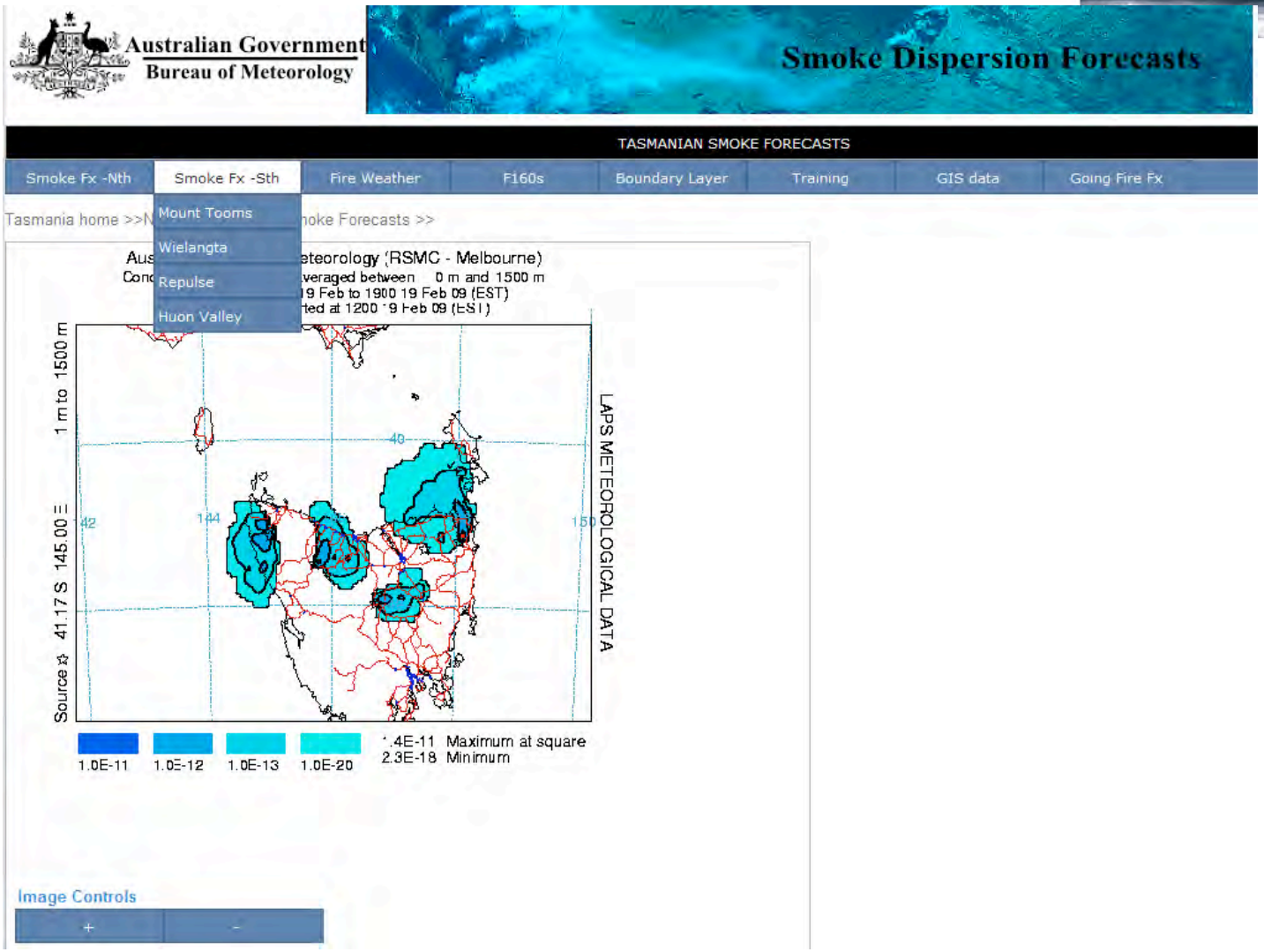
- Below the black bar above are menus linking to the various state pages.
- These menus exist on all smoke forecasting pages
- Placing the mouse cursor over a menu item may display further options.
- Left click your mouse to select the link you wish to pursue

Last Update

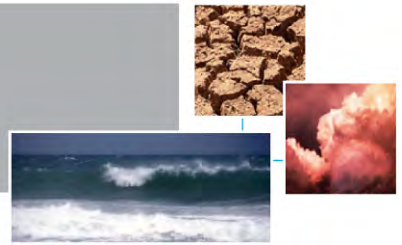
These pages were last updated at Thursday, 19-Feb-2009 01:04:11 GMT

Template Version 1.1

Product delivery – 3rd or 4th page

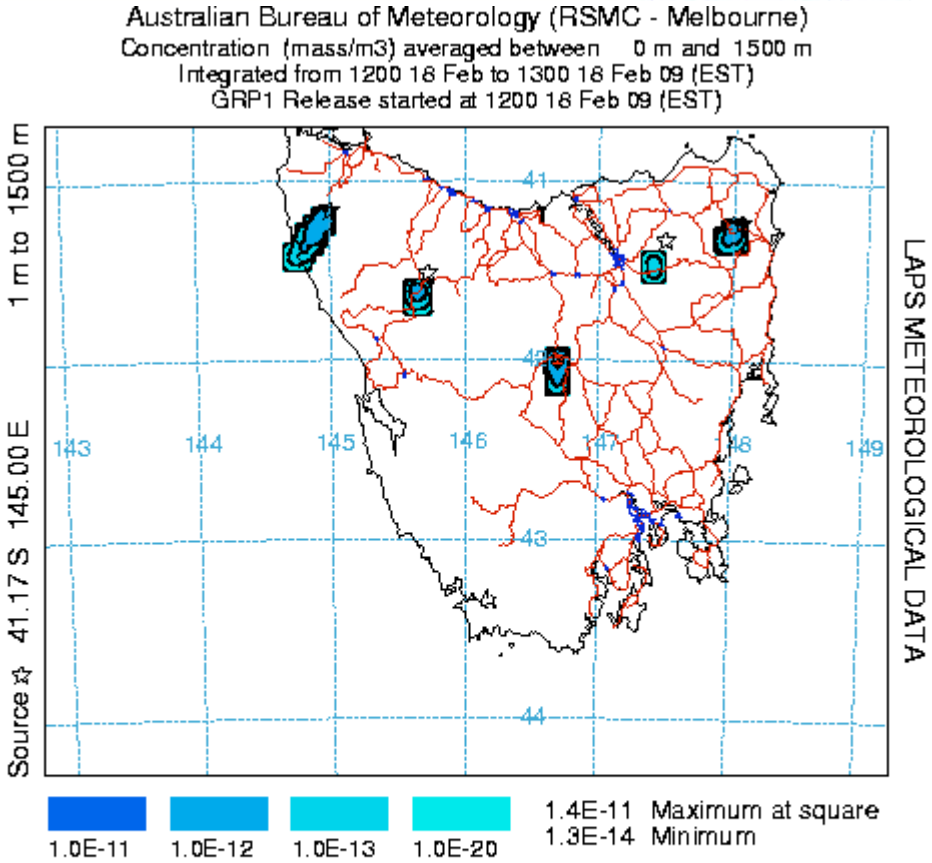


Product delivery – “smoke plumes”



Output Obtained

- Graphical depiction of the smoke plume
- Contours of relative concentrations



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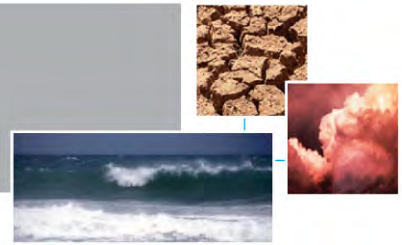
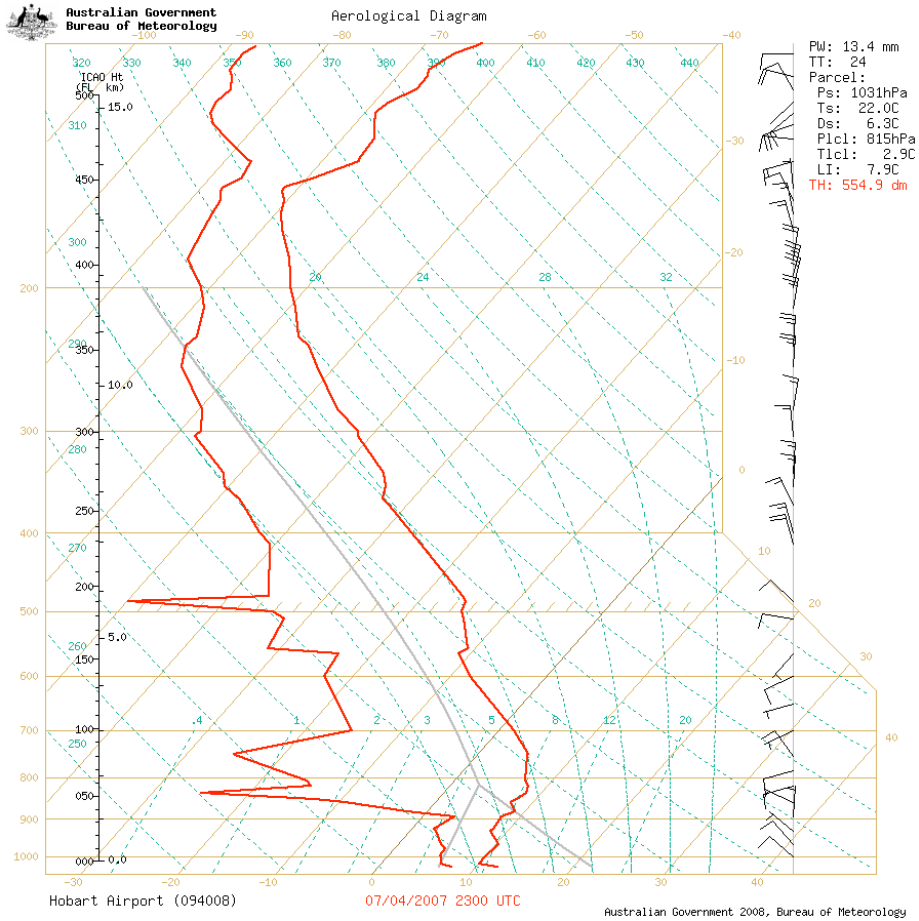
Product delivery -Decision support tools



Atmospheric temperature and wind profiles - atmospheric stability influences fire behaviour, plume rise, and dispersion



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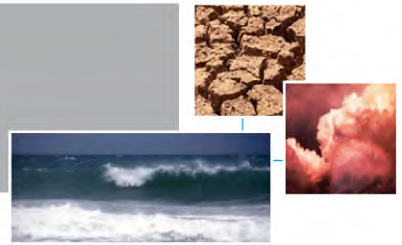
Product delivery - decision support tools

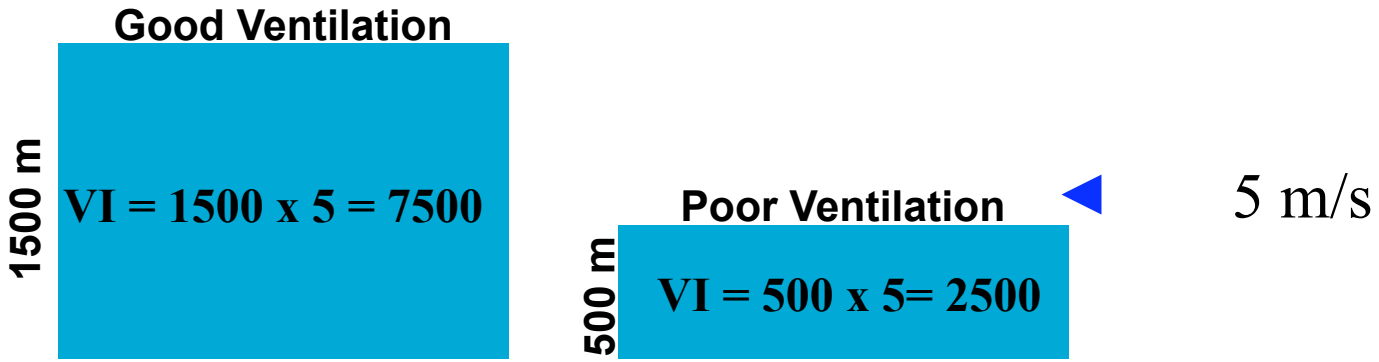


Ventilation Index:

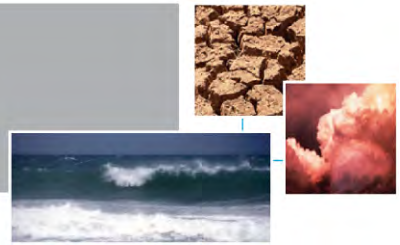
- Indicates the ability of the atmosphere to disperse pollutants

- calculated from the amount of air available for mixing ("the mixing depth") and the speed at which the air is passing.

Ventilation Index = Mixed Layer Depth (m) * Wind Speed (m/s)

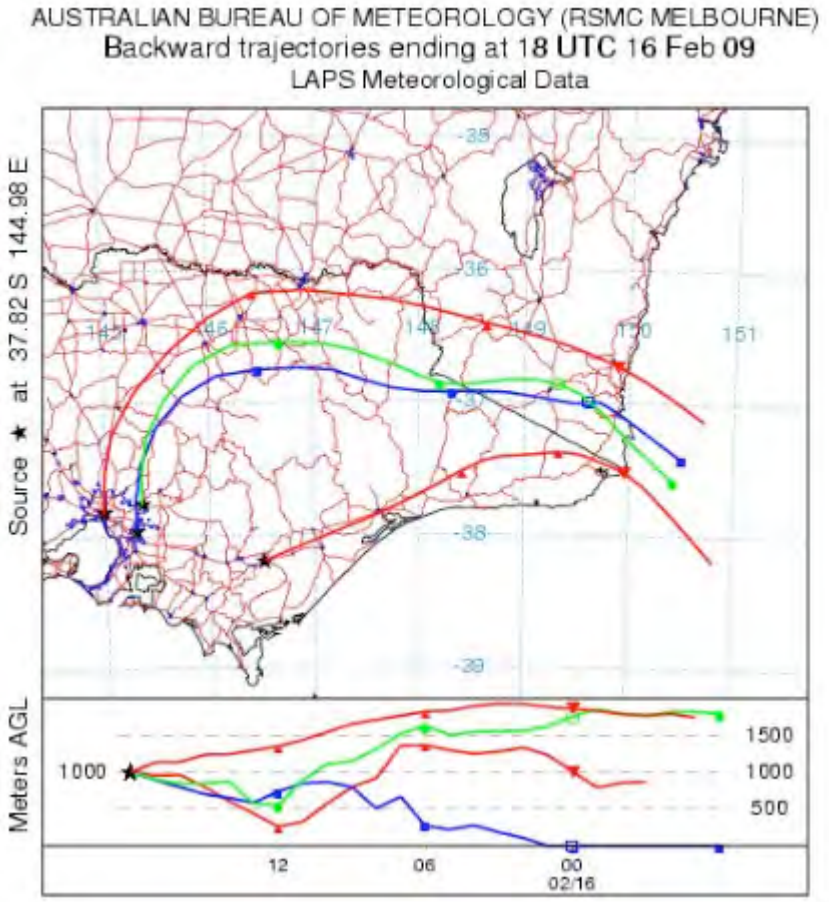


Product Delivery - decision support tools



Back Trajectories

– can be used to identify likely sources of smoke and likely paths taken from fires. Quick to calculate



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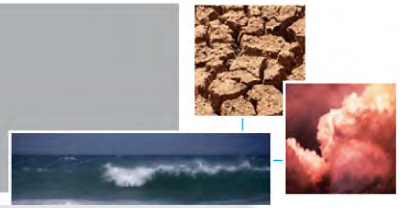
Training- on line training for users



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Smoke Dispersion Forecasting - Training Module

Tips for Navigation

- The menu is on the left of all pages excepting popups
- The course is composed of 7 modules
- The introduction, the summary and assessment modules do not contain any sub-modules (topics). The other modules are made up of a varying number of topics
- The current module/topic is indicated in blue on the menu
- At the bottom of the menu is a link back to the course introduction(this page) and/or to the next module (depending on which part of the course you a viewing)
- In the first page in a topic or module you will find a link at the bottom of the page back to the previous topic/module
- In the final page of a topic/module the is a similar link to the next topic/module

It is suggested that you approach the modules in the order they are listed below. Modules you have completed previously are shown in black. Uncompleted modules are shown in blue Simply click your mouse on the topic you wish to study.

- Basic Atmospheric Properties
- Atmospheric Stability
- Computer Models used in Smoke Forecasting
- Smoke Forecasts
- Course Summary
- Assessment

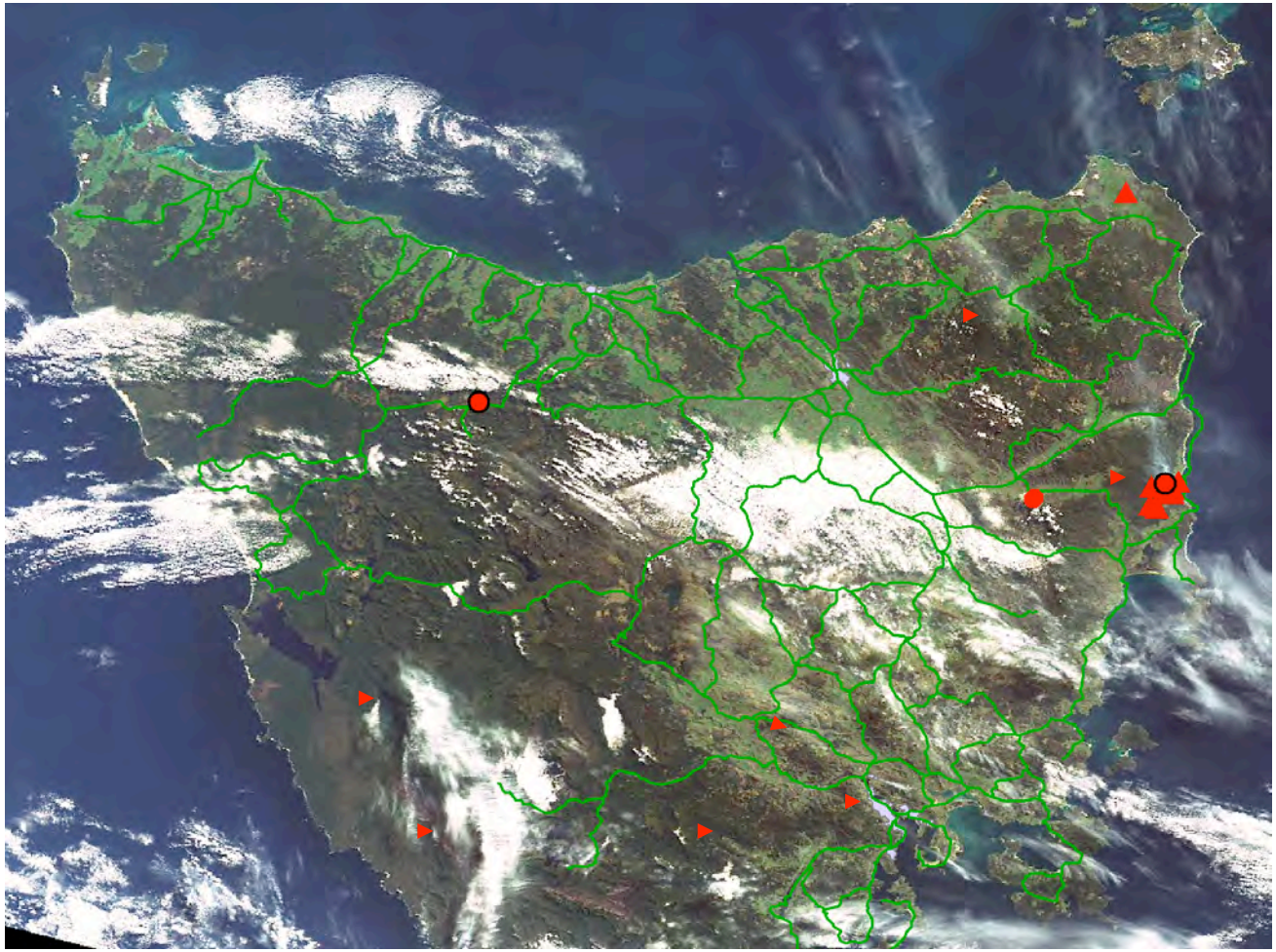
To assist you, important concepts you should remember on are indicated by this font

The text may contain words which are hyperlinked to "popup" explanations such as this next word; dispersion

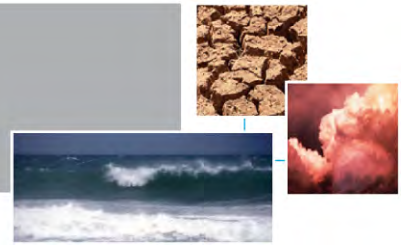
You may need to enable popups on your browser in order to see the explanations

Verification

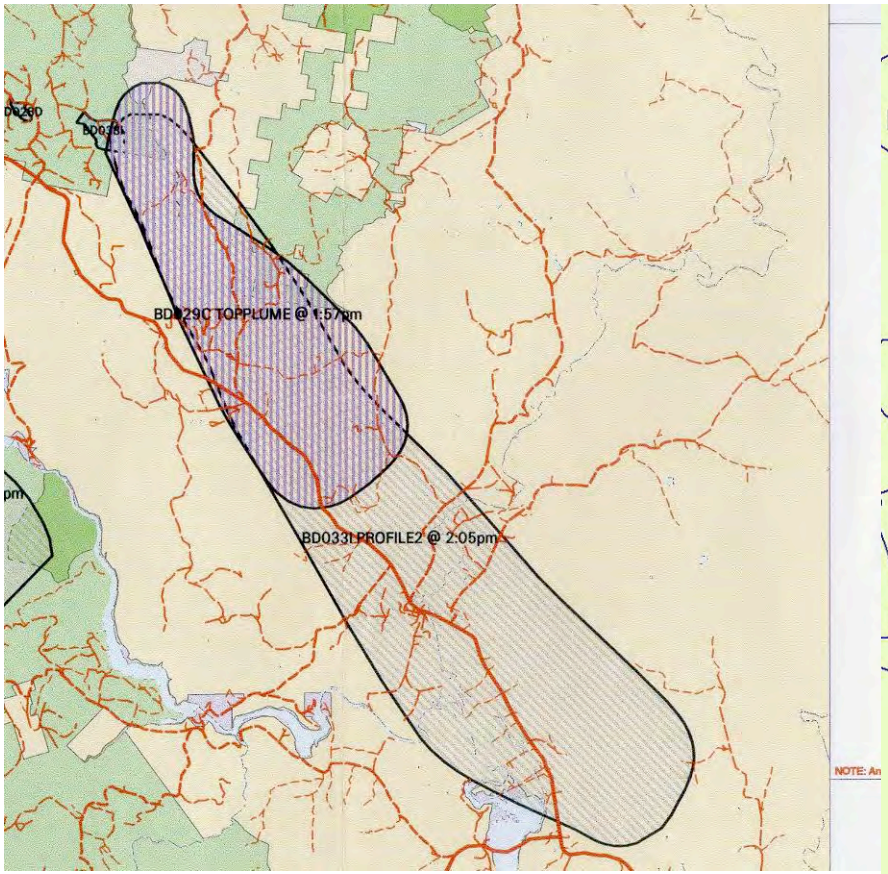
Verification

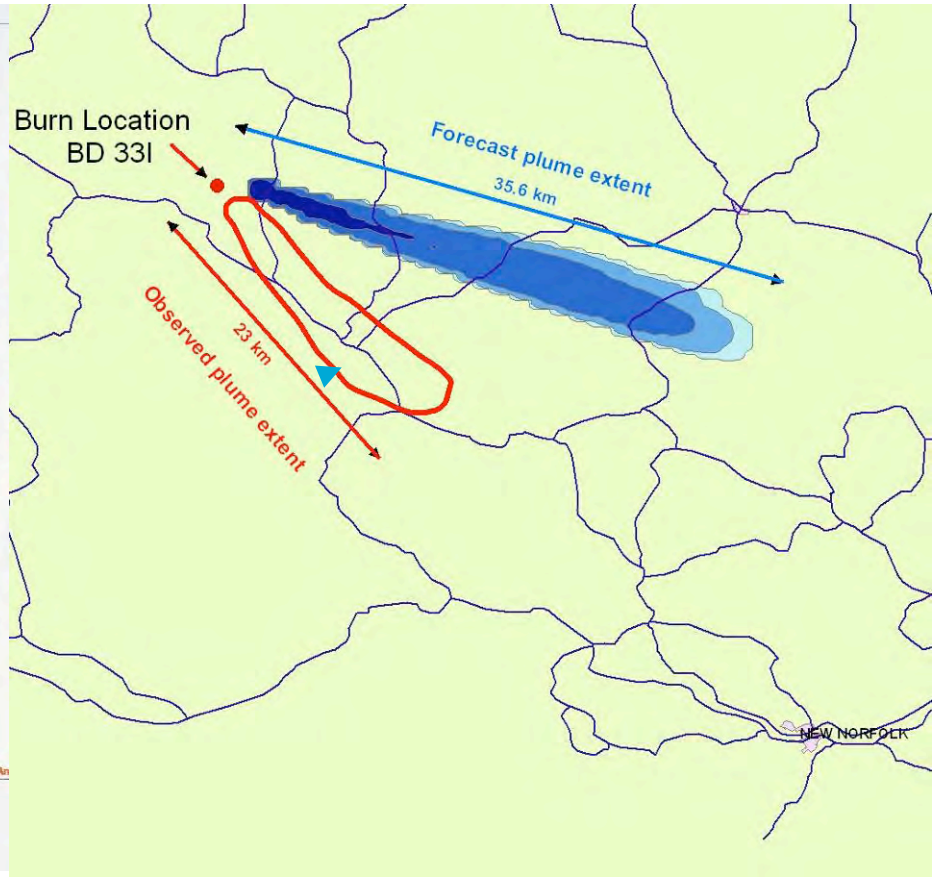


Verification



- **Using aircraft & GPS**





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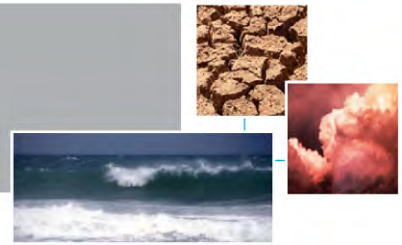
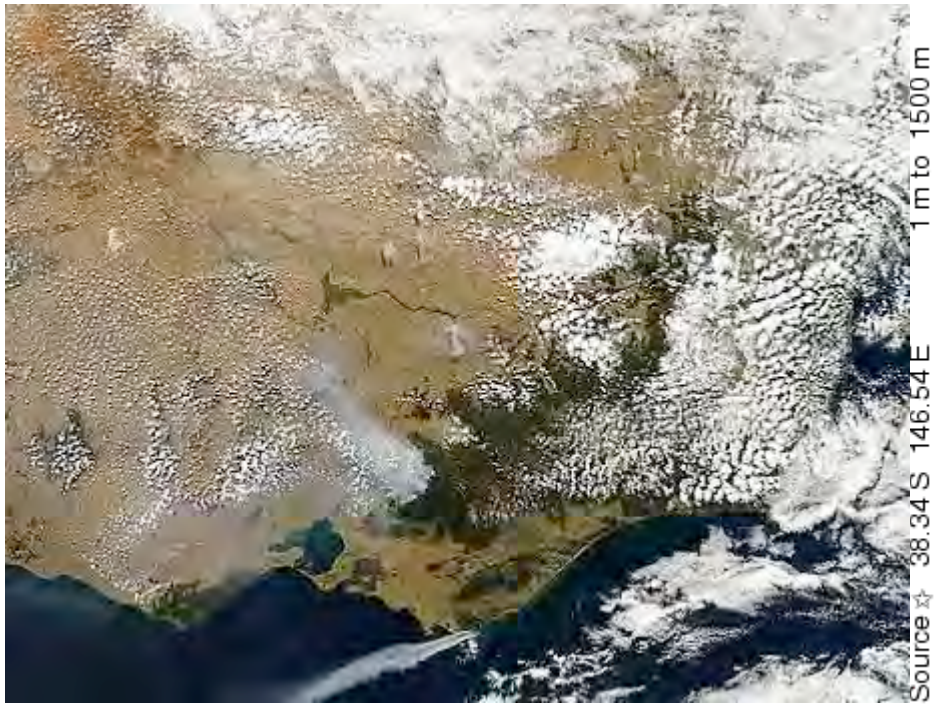
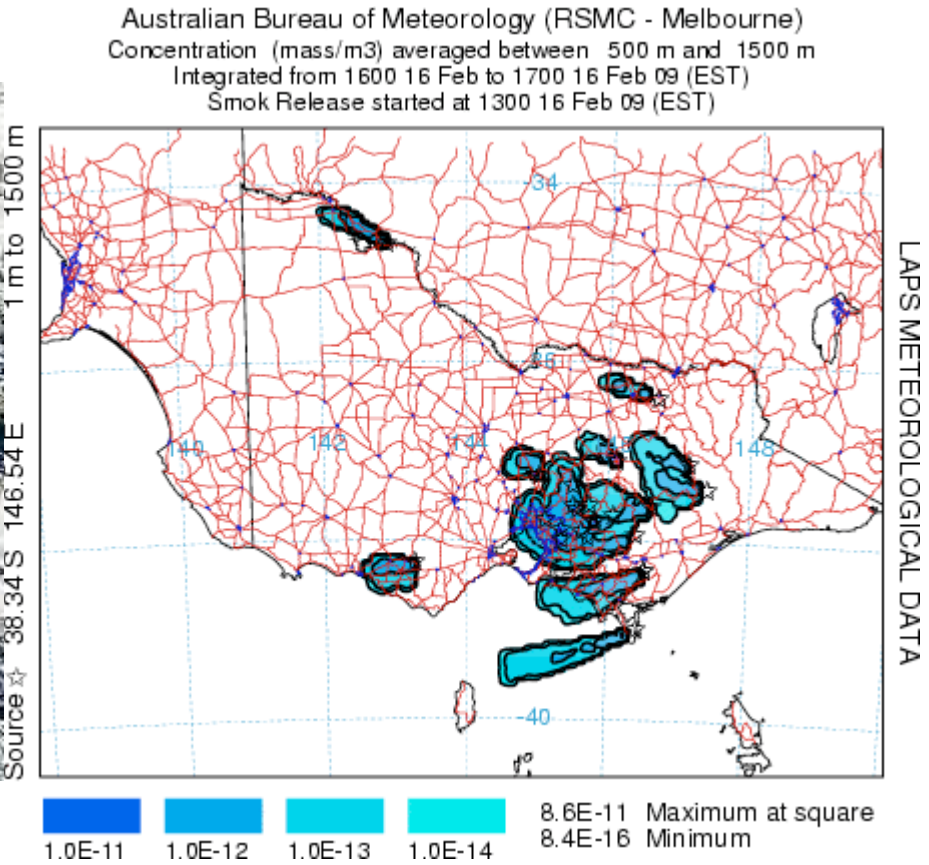


- **Satellite observations**

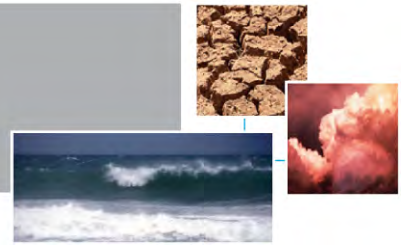




MODIS – 3:45pm Mon Feb 16

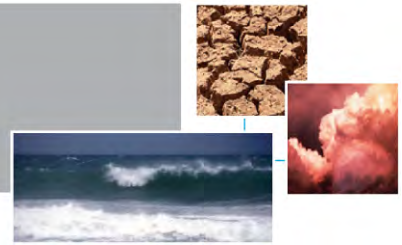
Forecast from going/contained fire locations

Verification –in situ measurements



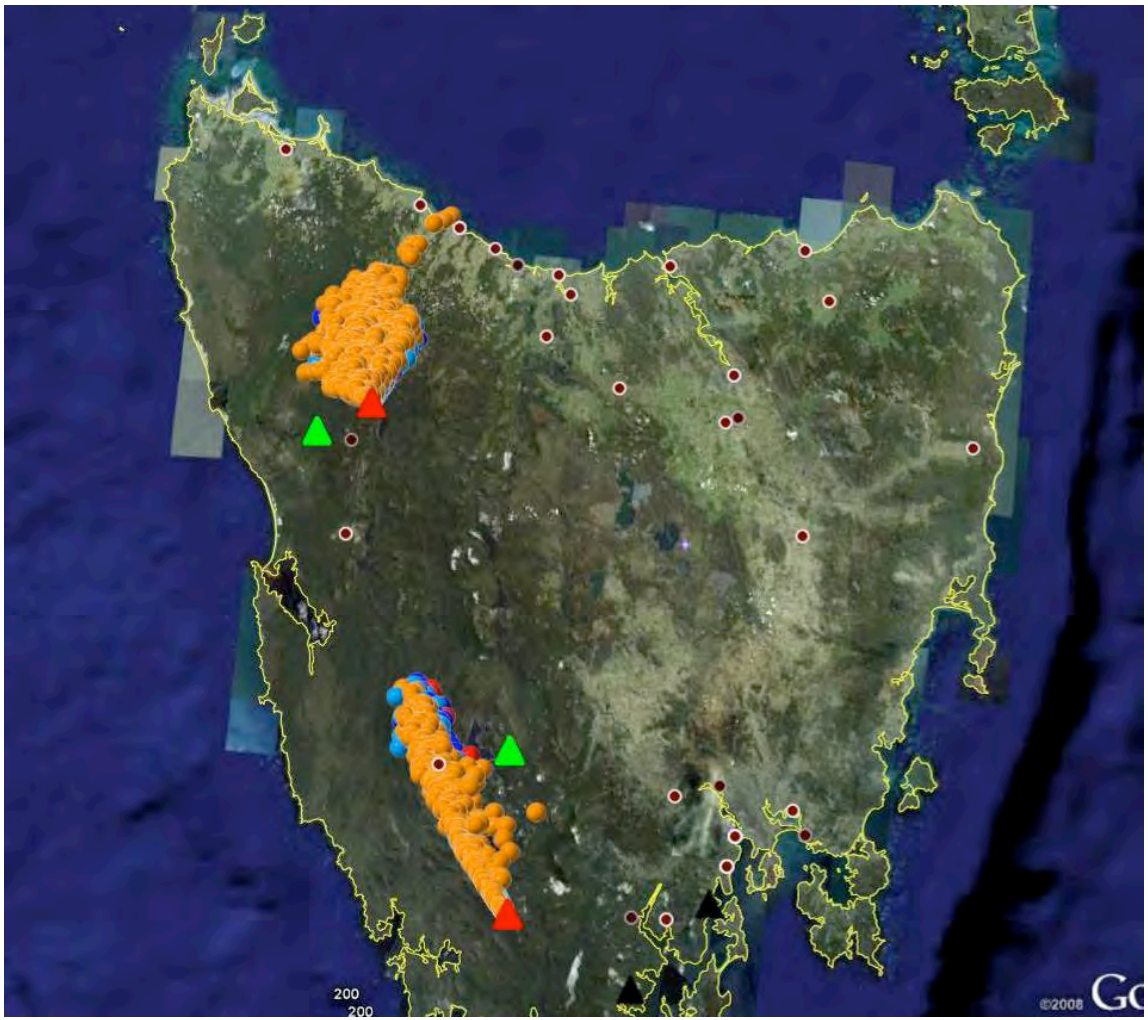
- In-situ measurements are “truth”
- Are expensive to install with sufficient density
- Are expensive to maintain
- If they are not sufficiently dense, then what constitutes an “error”

Using evolving technology



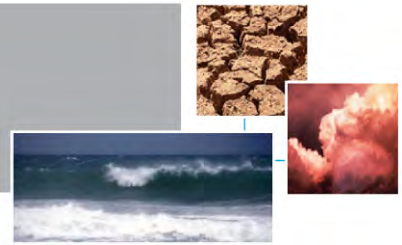
Google Earth plus dispersion model in "particle" mode.

Particles colour-coded for elevation



Ignition + 5hr

Causes of uncertainty

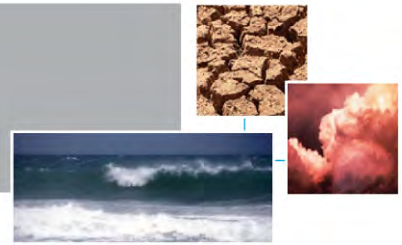


- **Emissions**
  - **due to large uncertainties in inputs smoke forecasting does not attempt to calculate the actual concentration of smoke.**

- **Fine Scale Topography**
  - **the model does not "recognise" small scale topographical features such as valleys. (why?)**

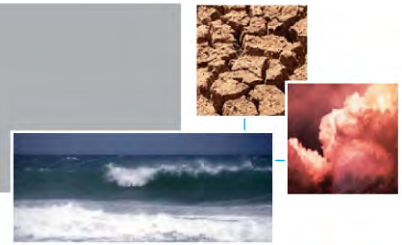
- **Pre-exisiting Smoke**
  - **No smoke emitted on previous days is currently taken into account (why?)**

Causes of uncertainty



- **Plume Rise**
  - **Winds vary with height so an accurate estimate of plume rise is important.**
  - **This is also dependent on how the temperature changes with height – the"stability"**
  - **Originally plume height was fixed**
  - **Now varies with time based on meteorology (mixed layer depth)**
  - **Future system will use heat release from fires to calculate plume rise**

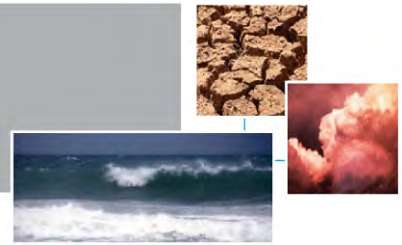
How to “quantify” uncertainty



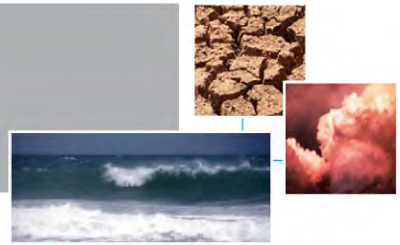
- Dispersion forecasts assume the underlying meteorological variables are correct.
- NWP models are “deterministic” ie produce 1 result which is assumed to be correct.
- Uncertainty in the “initial state” of the numerical forecast leads to forecast error
- Ensemble forecasts can be used to gauge the range of the errors and to produce a “probabilistic” forecast - ie a spread of possible forecasts

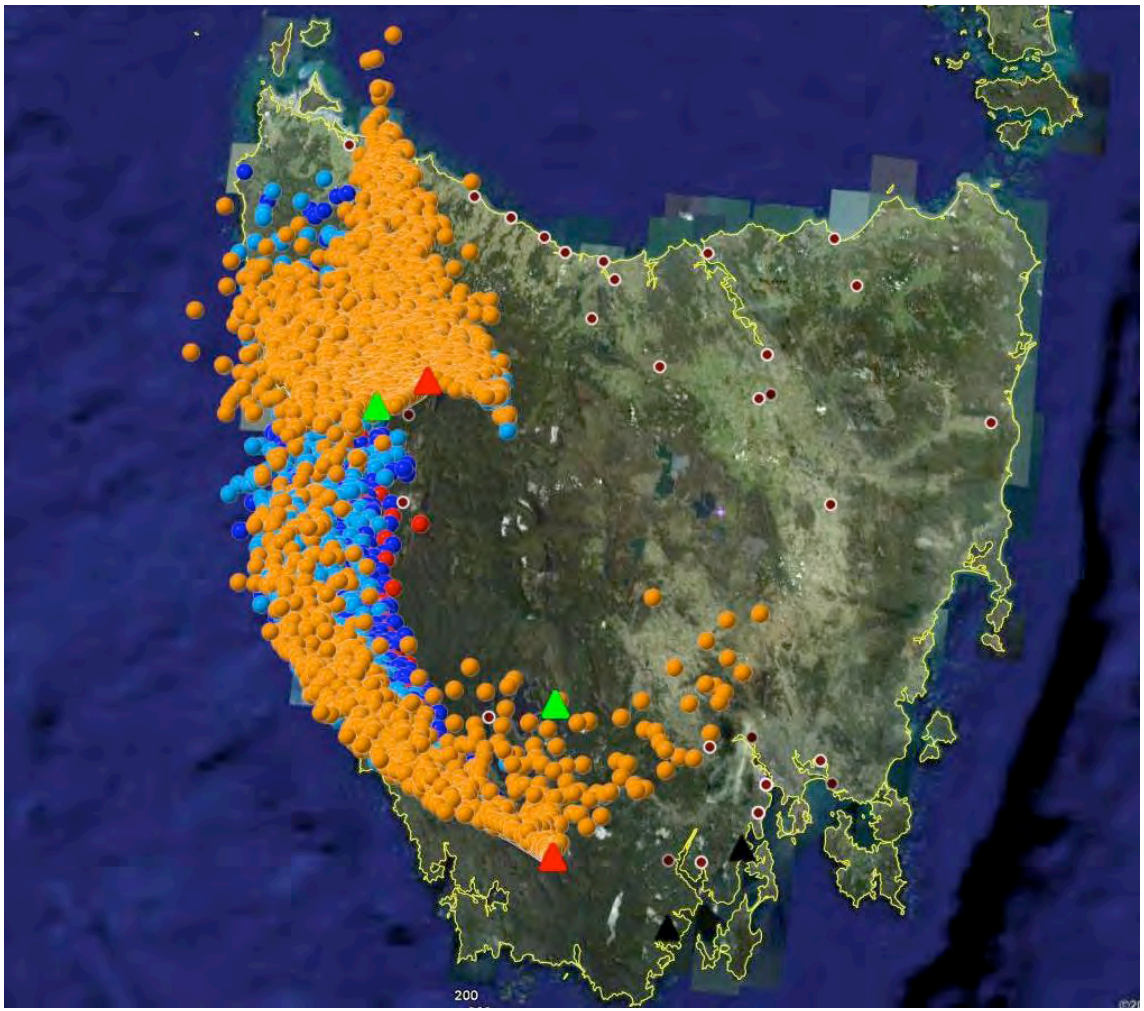
- The fuel/fire activity could also be input to the ensemble

Conclusions



- Smoke dispersion forecasts do what they were designed to do pretty well
- There's a lot we could do to improve if resources were committed to the task
- A more probabilistic approach could allow the uncertainty to be quantified. This would involve ensembles which include ranges of
    - Emissions - particulates/heat release??
    - Meteorology
    - Dispersion
- Higher resolution modelling (computer cost?)
- Product delivery – more/better graphics, GIS, Google Earth





Ignition + 10hr

THANK YOU

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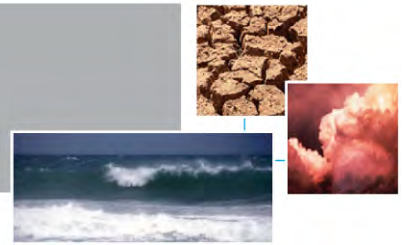
Why is the Bureau involved ?



- Dispersion is primarily governed by processes occurring in the lowest levels of the atmosphere
- Predicting Dispersion requires the calculation of multiple meteorological variables in 3 dimensions at multiple times.
- Variations in
  - temperature
  - wind speed
  - humidity
  - turbulence

  can significantly influence how a pollutant is distributed