User-oriented evaluation of fire spread predictions

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Australian Government
Bureau of Meteorology

NCAR
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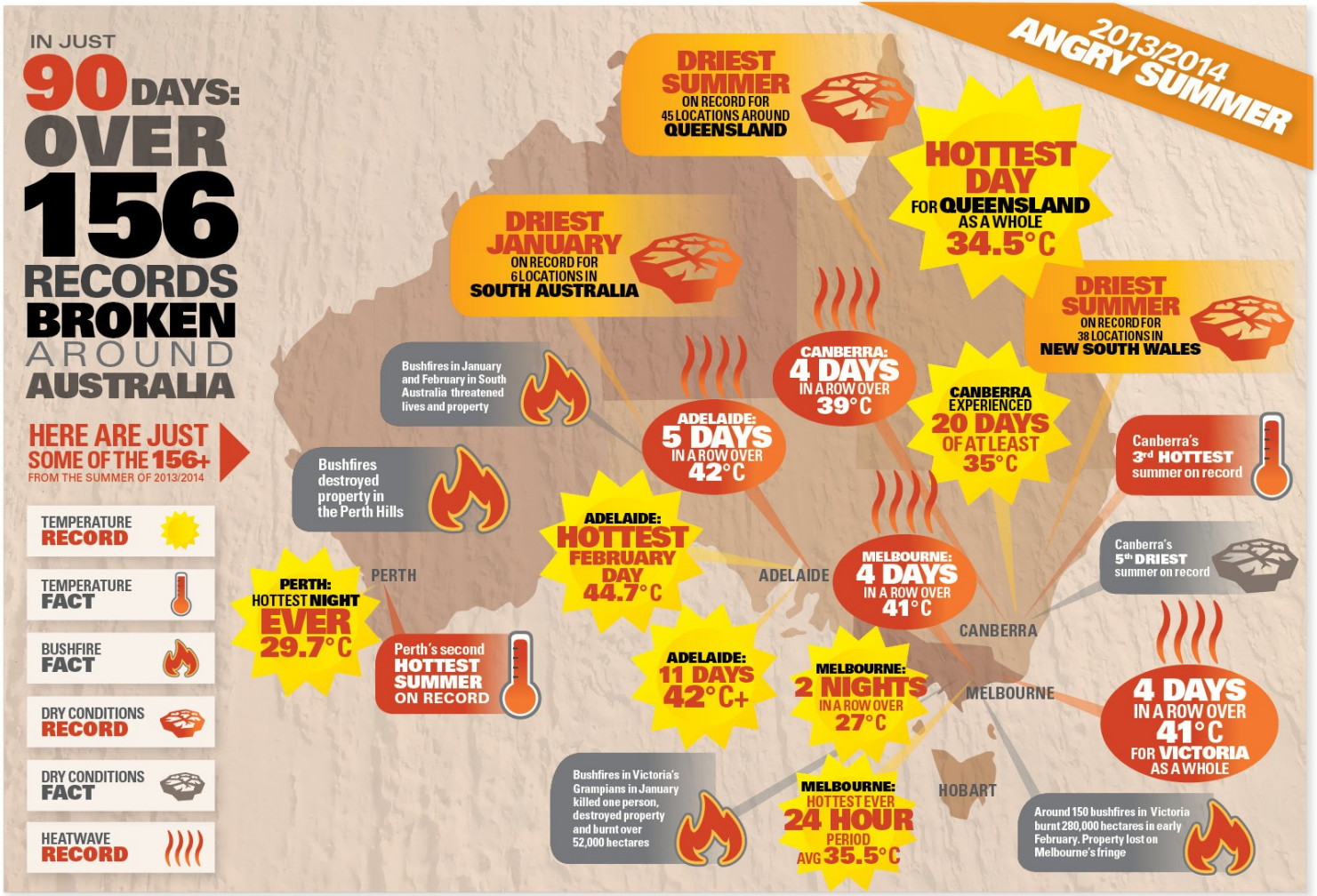
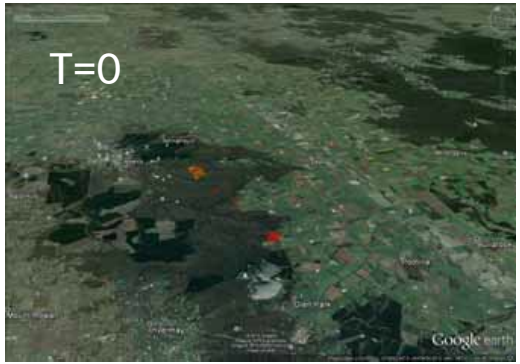
afac

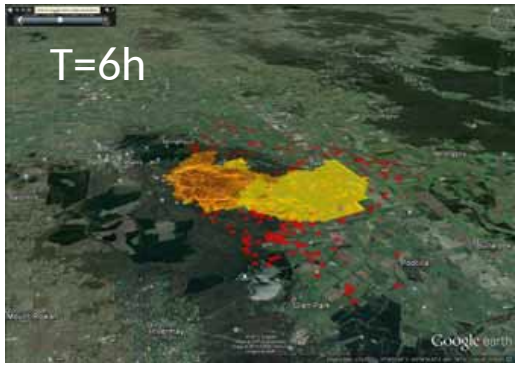


Source: BoM 2014a–h; The Age 18 January 2014; The Age 11 February 2014

www.climatecouncil.org.au

What is a fire spread simulator?



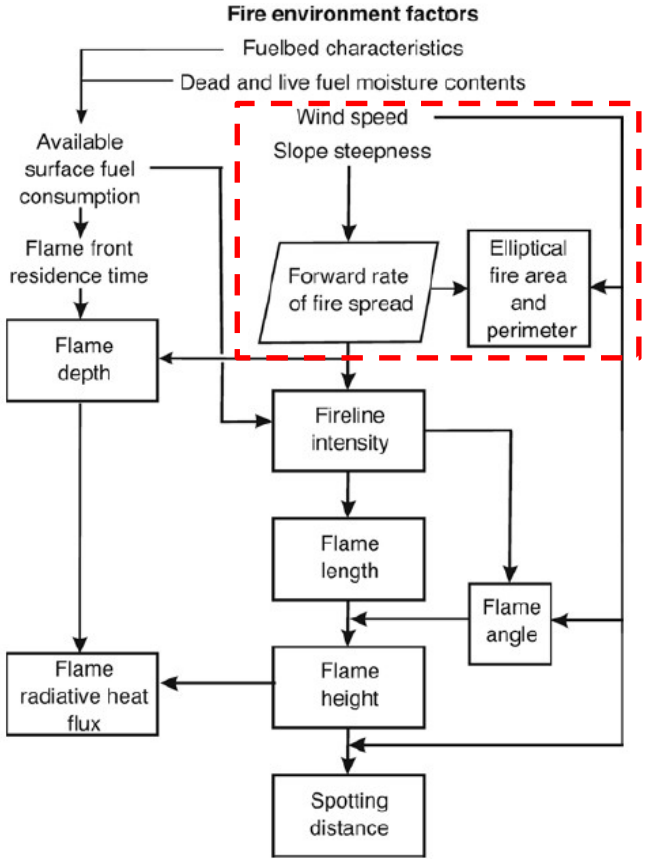


Tool that models fire characteristics (spatially):

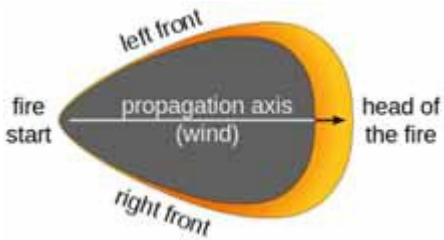
- Flame height
- Intensity
- Rate of spread
- Area of impact

A *simulator* is a collection of fire behavior *models* that can be used to infer the fire danger.

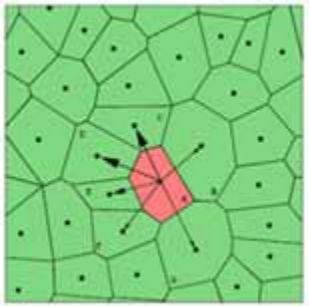
Weather forecasts are one of the principal drivers of the simulators.



Cell-based fire spread models

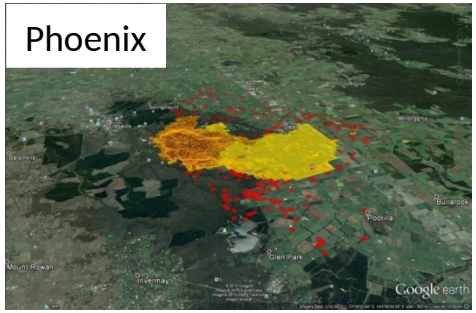


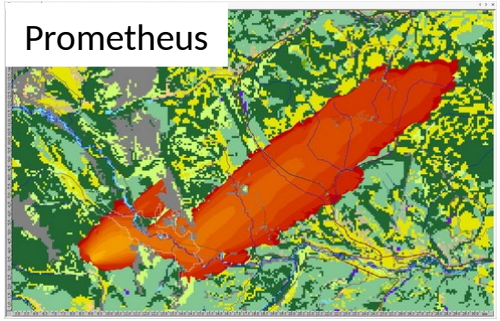
Geometric fire spread models

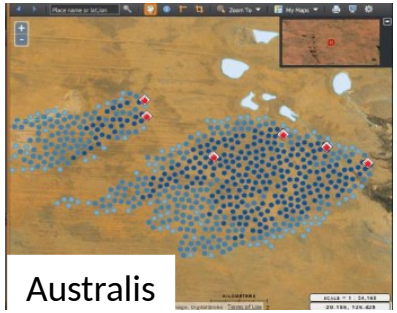


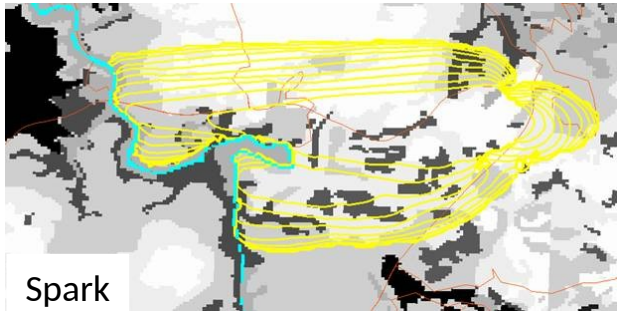
Adapted from: Fire Behaviour Knowledge in Australia, Cruz et, al. 2014, Bushfire CRC, Technical Report: EP145697

Fire spread simulators in Australia









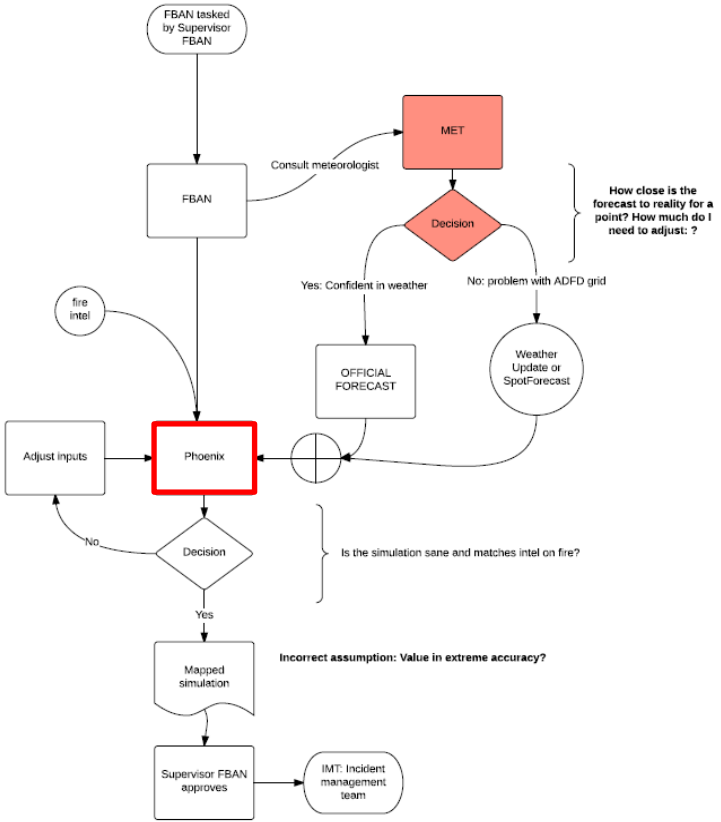
Which is best?

Bureau of Meteorology asked to run and evaluate these fire spread simulators for a set of common cases from around Australia

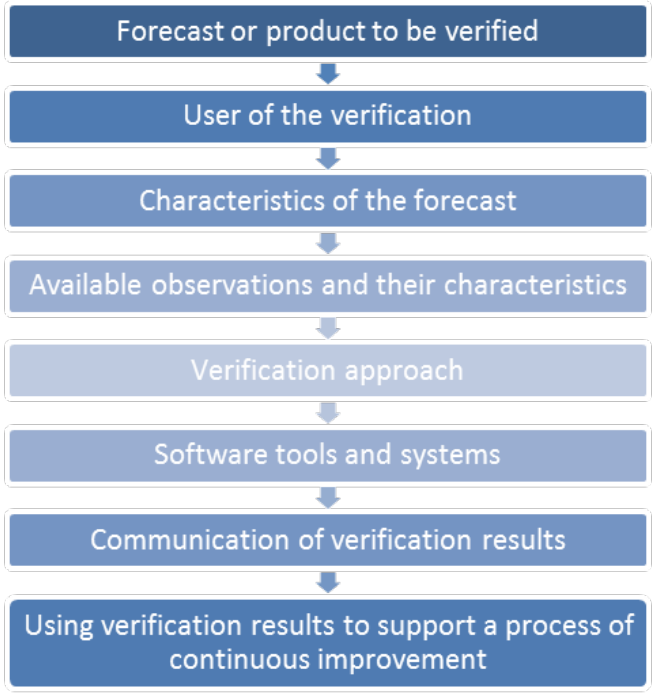
User focus of the evaluation

Consultation with end users (fire agencies)

- Kick-off workshop, site visits, consultations with simulator developers and fire behavior analysts
- Understand how they use fire spread simulators
- Understand what "good quality" means to them



Verification planning template



1. Forecast or product to be verified	
What is the forecast or product?	Simulator isochrones
2. User of the verification (complete for each type of user):	
Who is the user?	Fire behaviour analyst
How do they use the forecast?	Decision support
What aspects of forecast quality are important to them (e.g., bias, timing, absence of large errors, etc.)?	Biases in the rate of spread and direction? Right place right time Avoiding misses Can tolerate false alarms
For this user, what are likely to be the most effective ways to describe forecast performance (charts, statistics, verbal description, etc.)?	Maps and summary statistics
Can the user participate in the design of the verification – if so, how?	Absolutely – iterative drafting
3. Characteristics of the forecast	
Variable(s) and units	Where (location) and when (hours, minutes)
Spatial domain	Varies by event – rectangular box surrounding the fire
Point / area / grid (resolution)	Area (polygon)
Forecast range	At least 12 hours. Up to 4 days. In practice (24 hours max)
Temporal resolution of output	Hourly – can do half hourly
Instantaneous / averaged / accumulated	Accumulated
Update frequency	Variable and driven by changes in input data (new weather grids or fire intelligence).
4. Available observations and their characteristics	
Variable(s) and units – same as forecast, or proxy?	Line scans + GPS track from aircraft, GPS track from ground vehicles and some manual maps, satellite

What do users want to know?

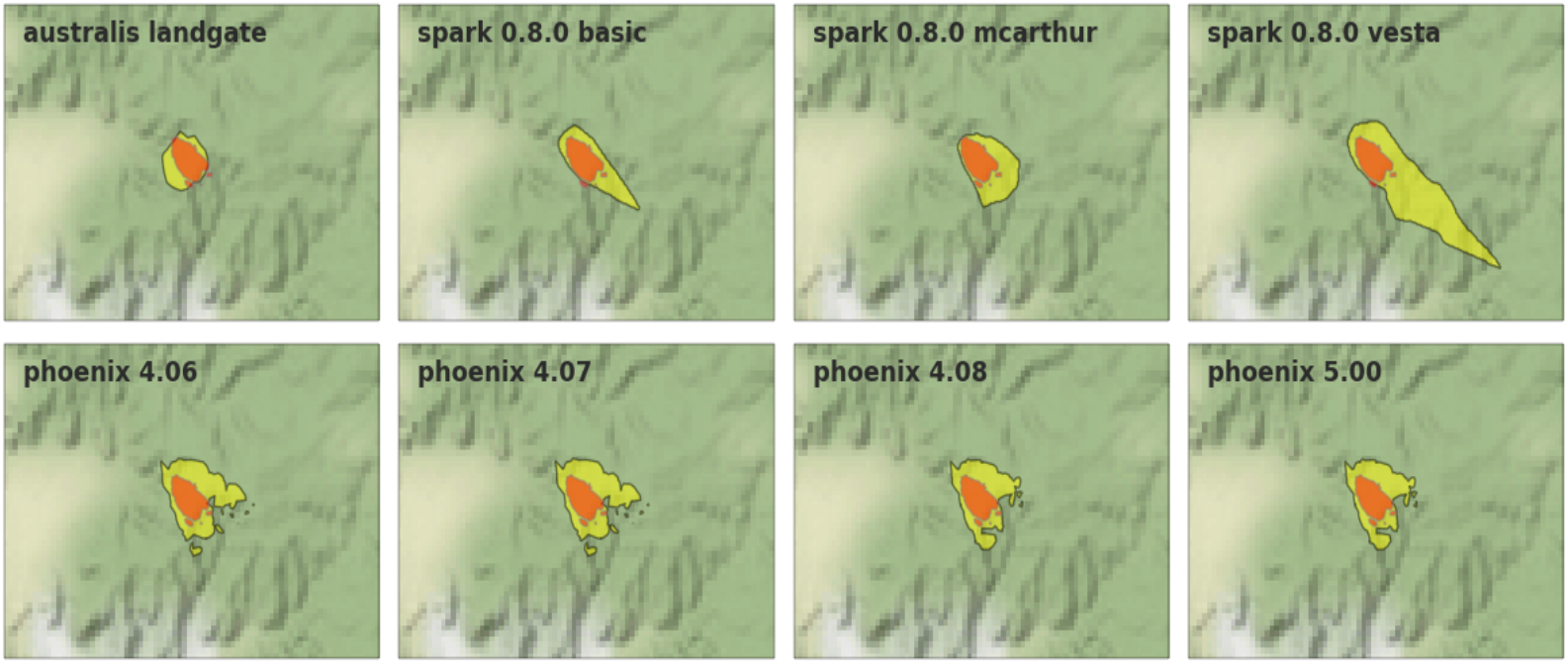
- Management-level users:
  - Which simulator is best?
  - Best for a particular case study?
- Fire behavior analysts (expert users):
  - How accurately does this simulator predict fire area, rate of spread, bearing?
  - How sensitive is this simulator to variations in weather, fuel, ignition location/time?
- Simulator developers:
  - How can the uncertainty in weather inputs be quantified to assist in the discrimination between model errors and input errors?

Data

10 case studies for this project:

- Fire boundaries (isochrones) from line scans or reconstructions
  - Limited as agencies focus on protection of life and property
  - Prefer cases without suppression
- Weather
  - Official weather forecast grids
  - Weather station observations
- Fuel layers from agencies
- Topography

Sample simulations

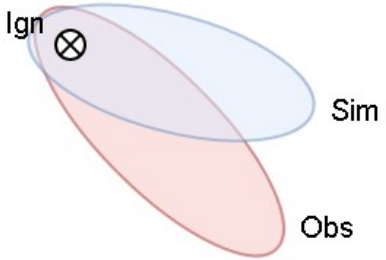


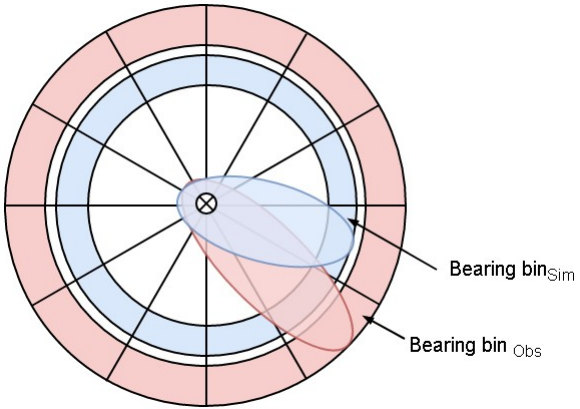
State Mine fire, New South Wales, 16 October 2013

Spatial verification metrics

Summary metric

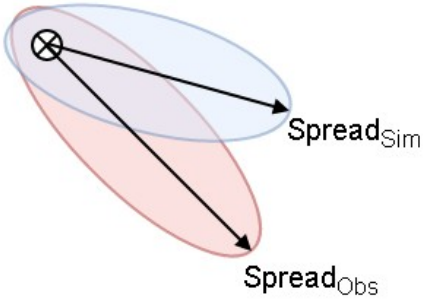
- Threat score

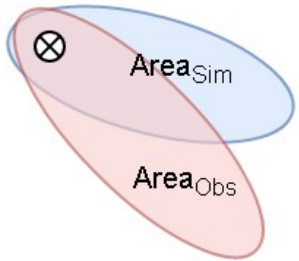




Diagnostic metrics

- Bearing error
- Forward spread error
- Area error

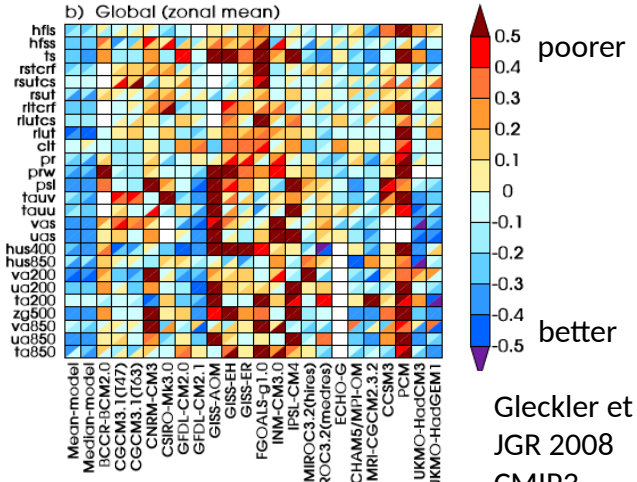




Evaluation approach

For each simulator and all case studies:

- Baseline performance
  - Simulate fire spread using forecast weather in ignition grid cell(s)
- Sensitivity studies
  - Perturb input weather
  - Perturb fuel, ignition location
- Relative and absolute performance

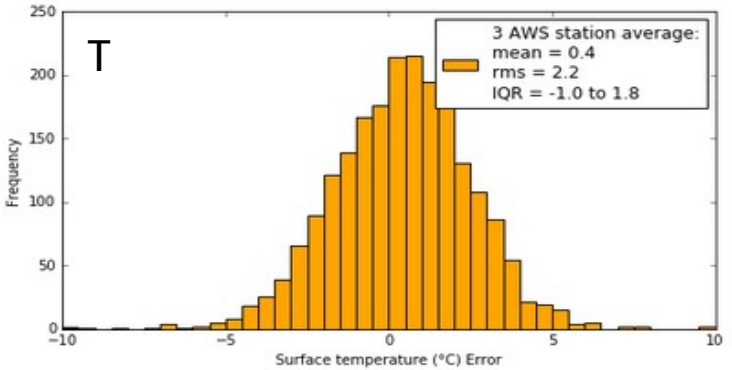


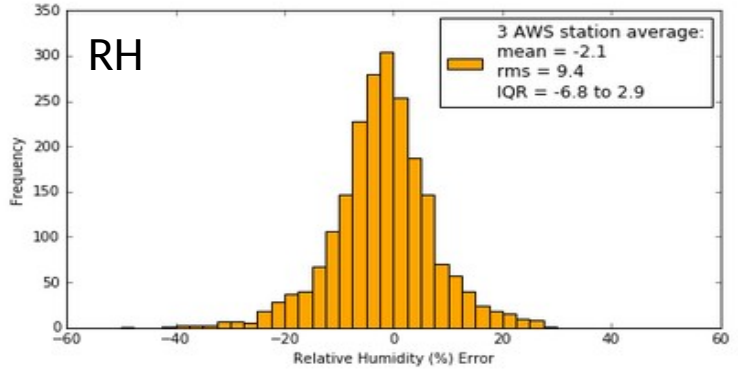
Gleckler et al.
JGR 2008
CMIP3

Estimating uncertainty in weather inputs

For each case:

- Verify 1-day weather forecasts at fire location against observations averaged over three "nearest" AWS
- Bin $X_{fcst} - \overline{X_{obs}}$ each hour for all days of month in which fire occurred
- Use error PDF as template for perturbing weather inputs

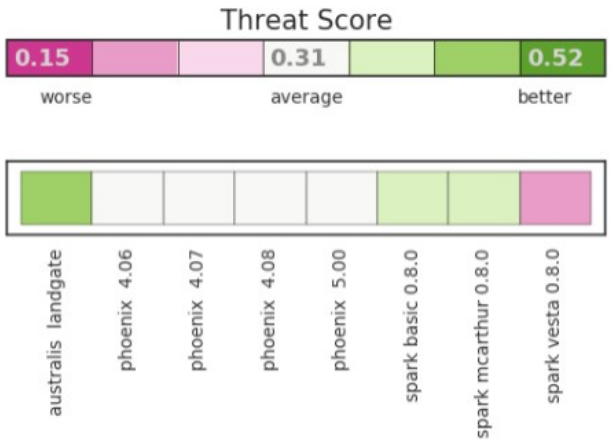




High level view - relative performance

- Management-level users want to know:
  - Which simulator is best?
  - Best for a particular case study?
- Compare aggregate accuracy over all perturbed inputs to the whole population (overall or for each case)

Dashboard



Deeper view – accuracy & sensitivity

- Fire behaviour analysts (expert users) want to know:
  - How accurately does this simulator predict fire area, rate of spread, bearing?
  - How sensitive is this simulator to variations in weather, fuel, ignition location/time?
- Box size shows sensitivity (how does IQR compare to all IQRs?)

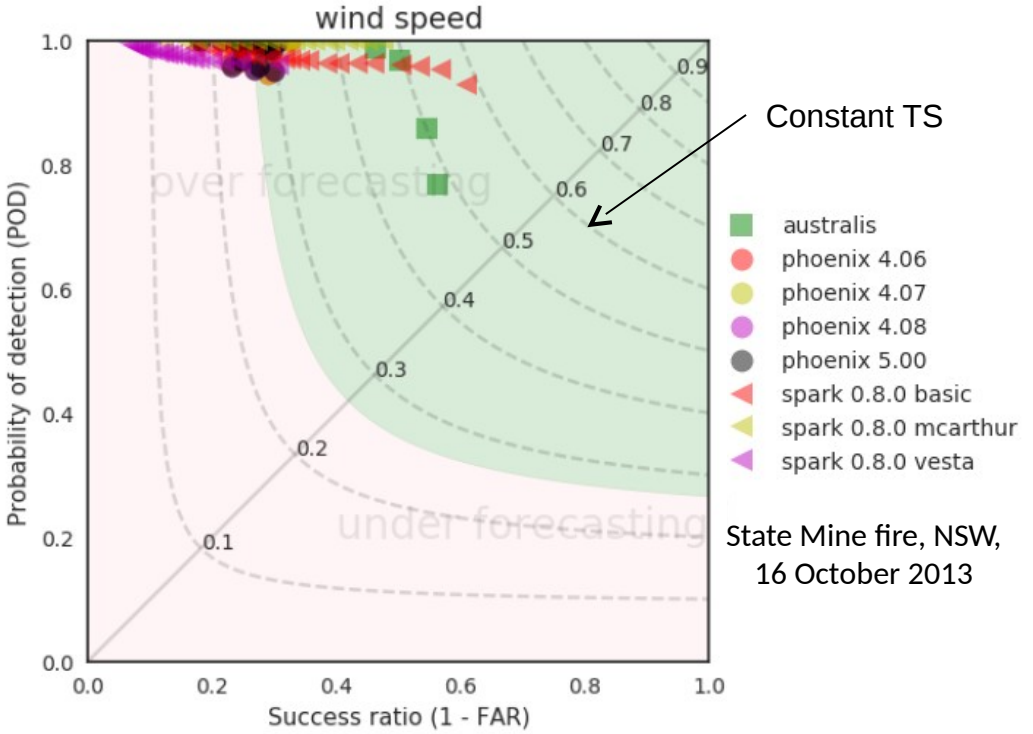
Modified Hinton diagram

State Mine fire, NSW, 16 October 2013

Deeper view – accuracy & sensitivity

- Fire behaviour analyst (expert users) want to know:
  - How accurately does this simulator predict fire area, rate of spread, bearing?
  - How sensitive is this simulator to variations in weather, fuel, ignition location/time?
- Pink = below median,
  Green = above median

Categorical performance diagram



State Mine fire, NSW,
16 October 2013

What did we learn?

- No single simulator stood out overall as being superior to the others and none performed well in all circumstances. All simulators over-predicted some fires and under-predicted others.
- Simulators (and fires) are sensitive to weather, particularly wind. This highlights the value of an ensemble approach to the operational use of fire spread simulators.
- This evaluation framework will be a community tool for evaluating fire spread simulators, and has already prompted the community to make significant improvements to their simulators.
- Need more cases, and standards for observing and reporting fire behavior.