The development of a pyrocumulonimbus prediction tool

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Inglewood Fire 5 Dec 2016: Nick McCarthy

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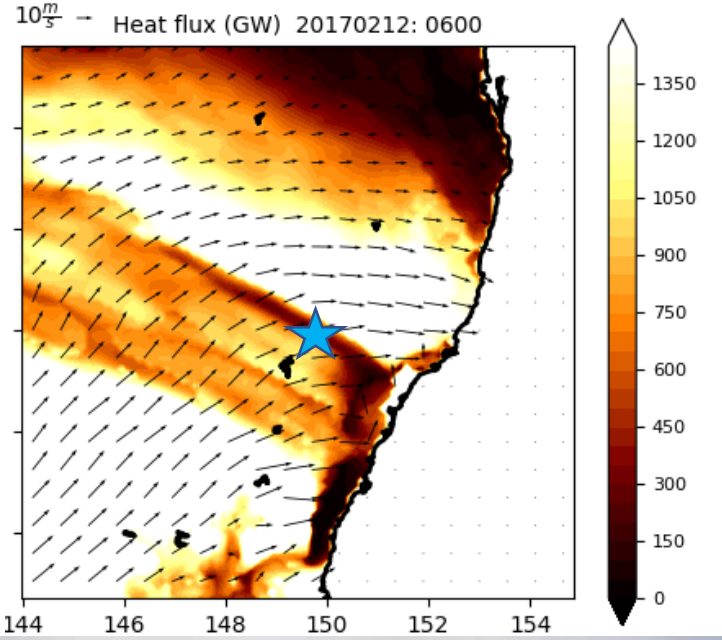
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

Introduction

- PyroCb Firepower Threshold (*PFT*)
- Background: Plume structure and behavior
- Briggs plume model
- How to Identify *PFT* ingredients on a thermodynamic diagram
- Sample *PFT* results



Sir Ivan fire: 5:20 PM, 12 Feb 2017, looking NE
http://www.bbc.com/news/world-australia-38952206

Background

- Buoyant plumes entrain air from the environment
- Entrainment dilutes the plume and reduces its buoyancy
- The initial buoyancy is proportional to the firepower
- The rate at which the buoyancy is reduced by entrainment, determines how rapidly the plume rises and how high it rises

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Background

- Plume buoyancy is influenced by:
  - Fire size and intensity (firepower)
  - Background wind (U),
    which together largely determine the plume-rise-height (z).
- Solutions to the Briggs model describe the relationship between these terms

Briggs Model

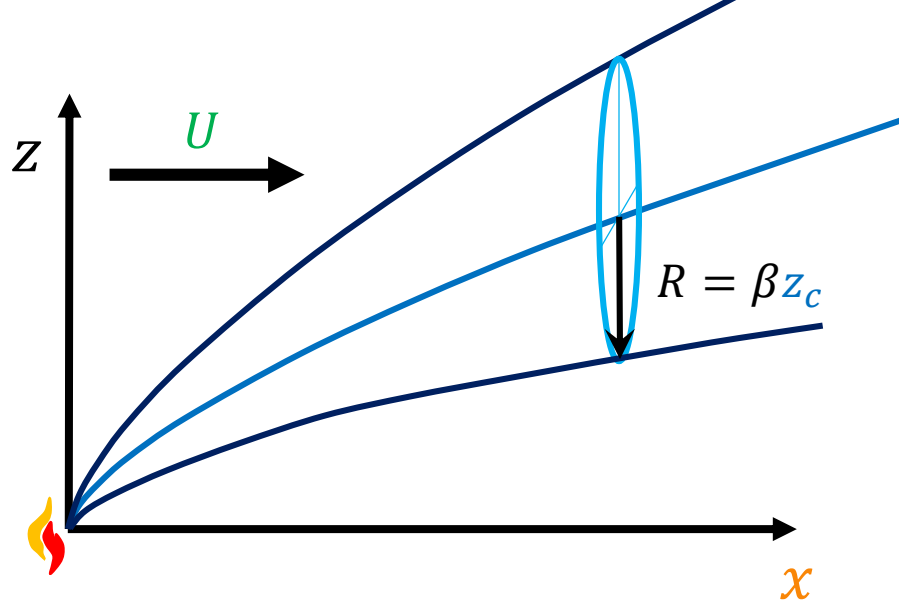
- $z_c = \left[\left(\frac{3}{2\beta^2}\right)\frac{B_{flux}}{\pi}\right]^{\frac{1}{3}} \frac{x^{\frac{2}{3}}}{U}$

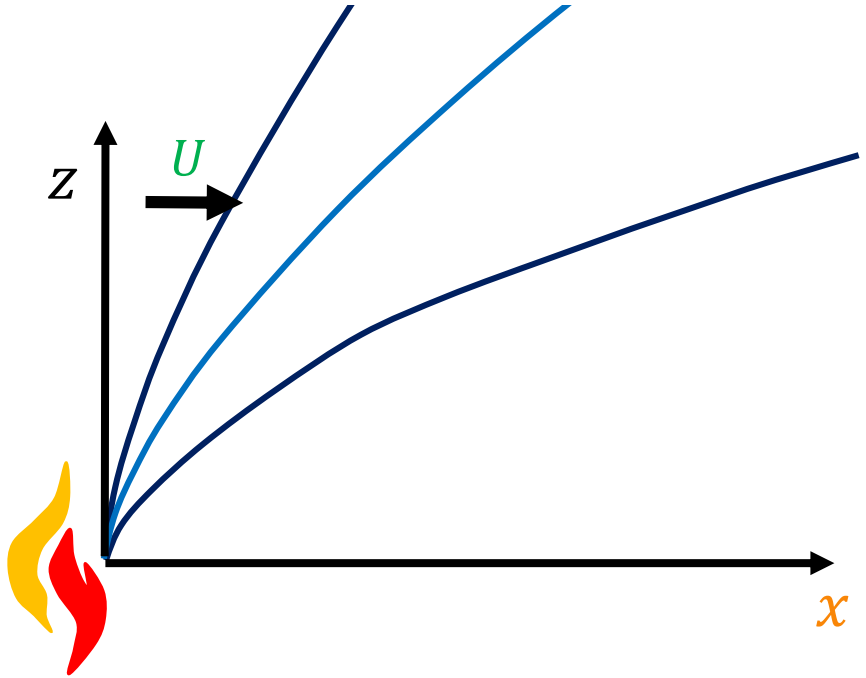
To double the plume height:

Increase firepower by ***8*** times

Or

Halve the wind speed

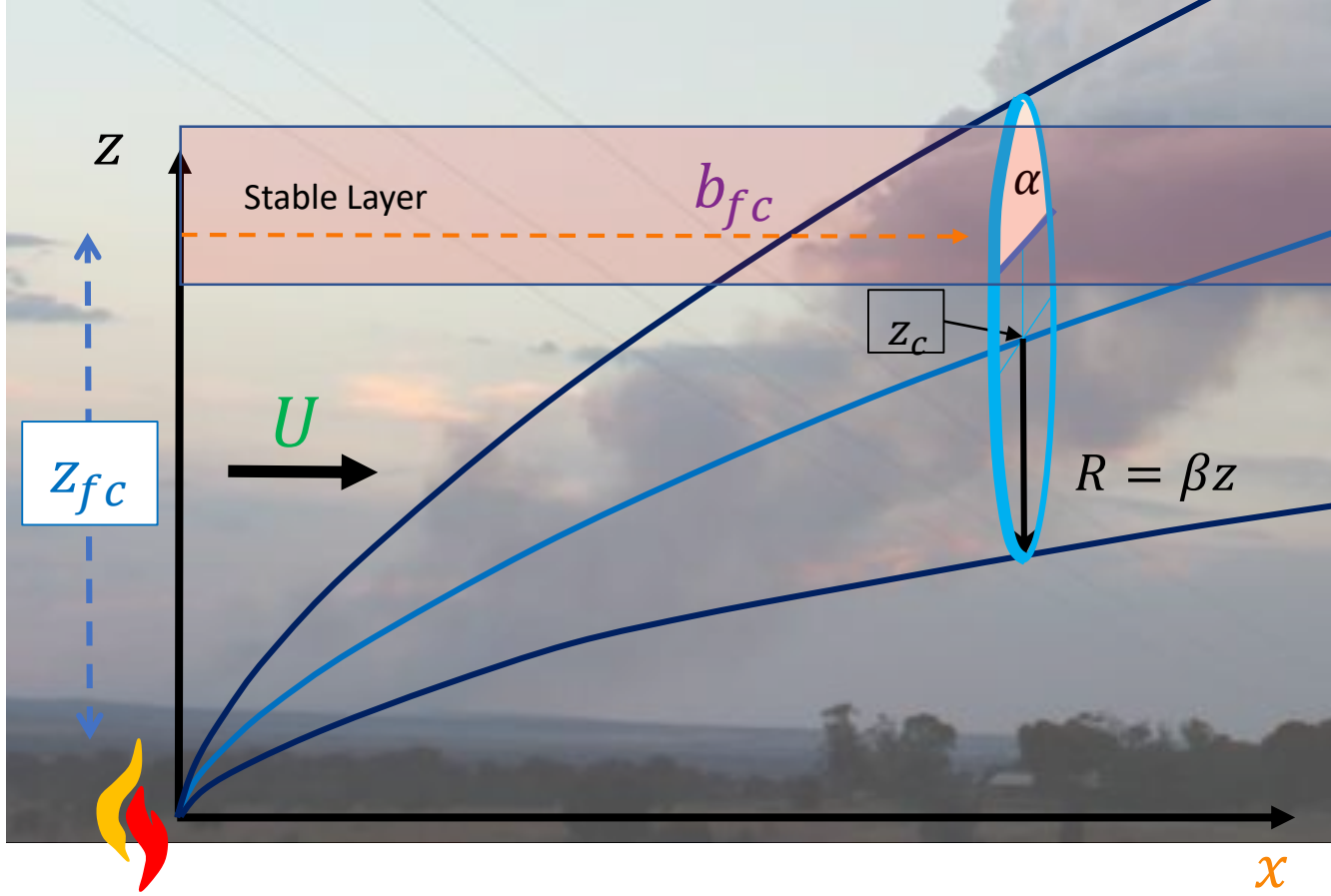




Briggs Model

An equation for the buoyancy distribution within a Briggs plume is inverted:

- $PFT = \left[\frac{\pi \rho C_{pd} \theta_{ML}}{g}\left(\frac{\beta I}{(1+\alpha\beta I)}\right)^2\right]$ Constant $(z_{fc})^2 U b_{fc}$



- z_{fc} : The larger z_{fc} the higher the plume must rise - *more fire*power *required*.
- U : The stronger U the *more fire*power *required* to counter the plumes tendency to bend over.
- b_{fc} : A larger capping inversion requires a hotter plume and thus *more fire*power.

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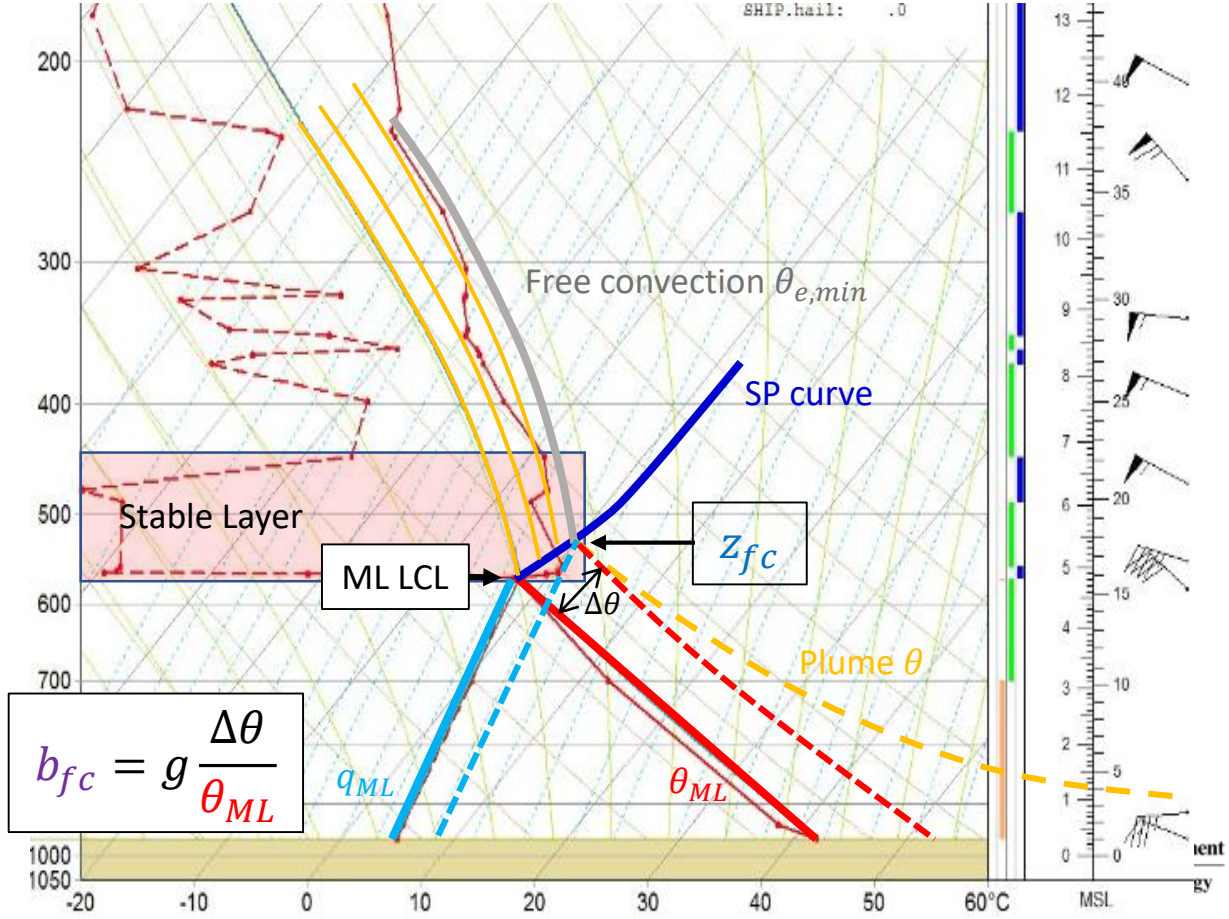
PFT Ingredients

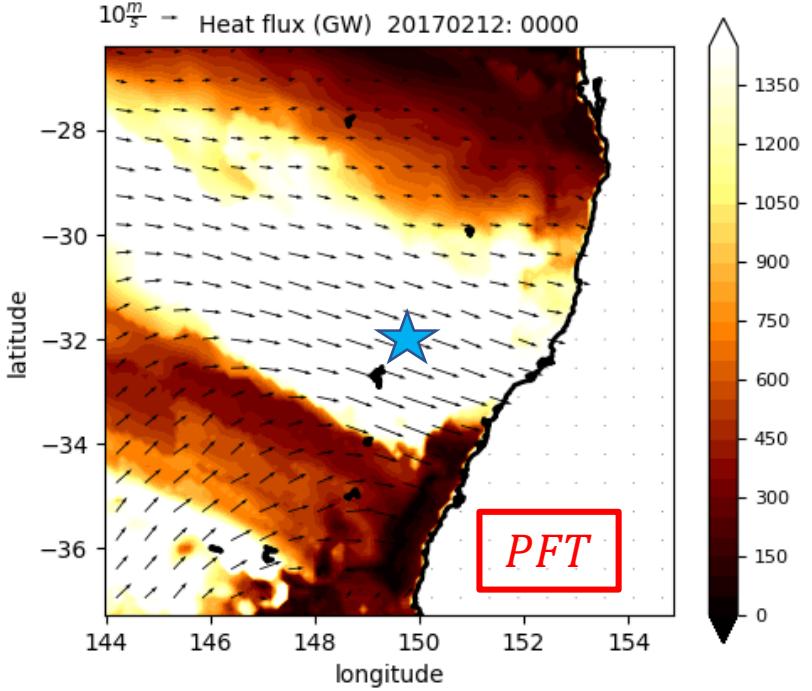
- Use pyroCu thermodynamic model to determine *PFT* ingredients.
  - $PFT = C(z_{fc})^2 U b_{fc}$

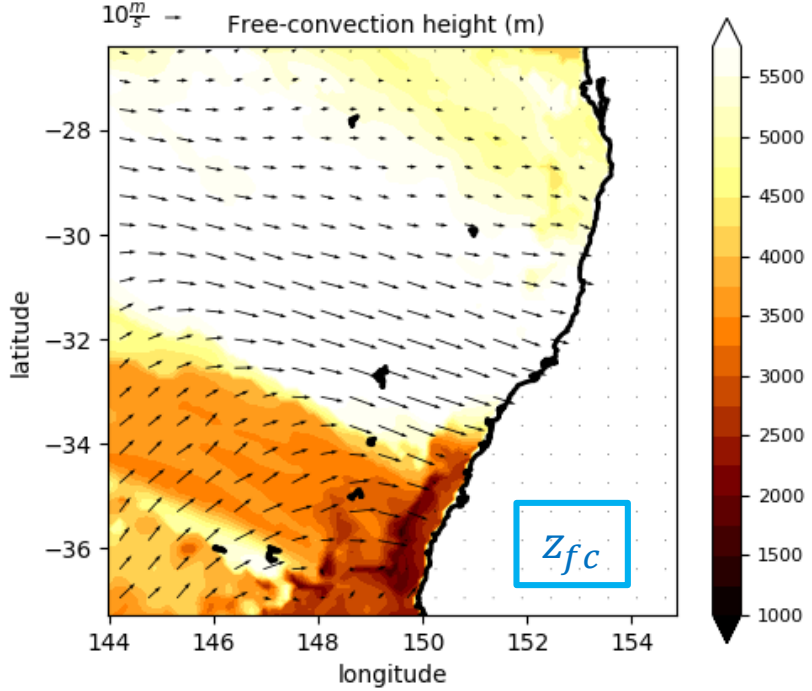


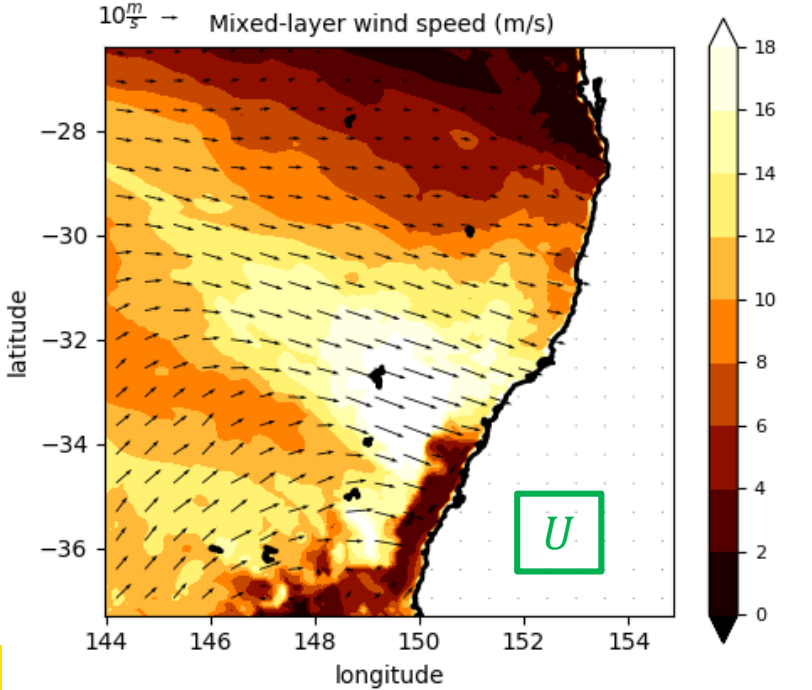
Sir Ivan Fire

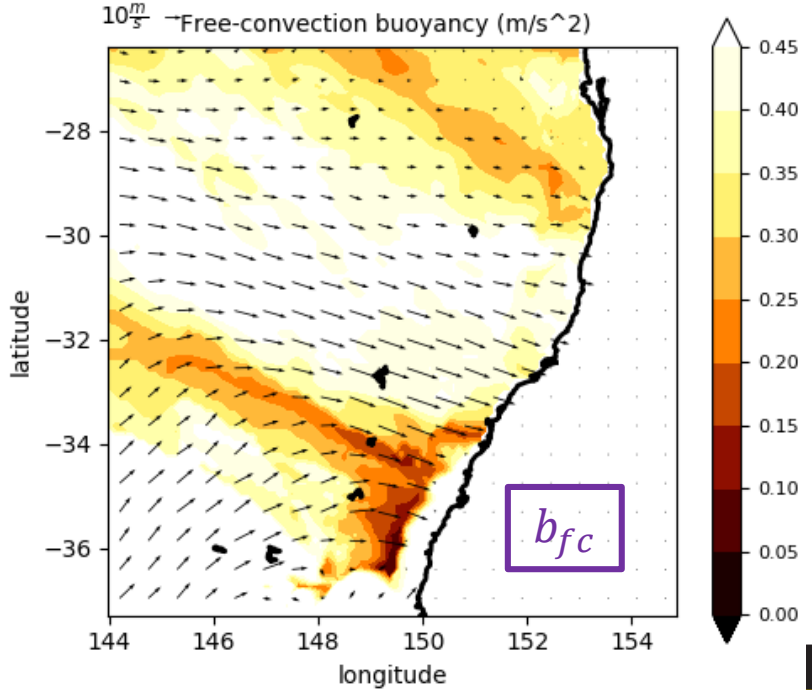
- $PFT = C(z_{fc})^2 U b_{fc}$

11 AM







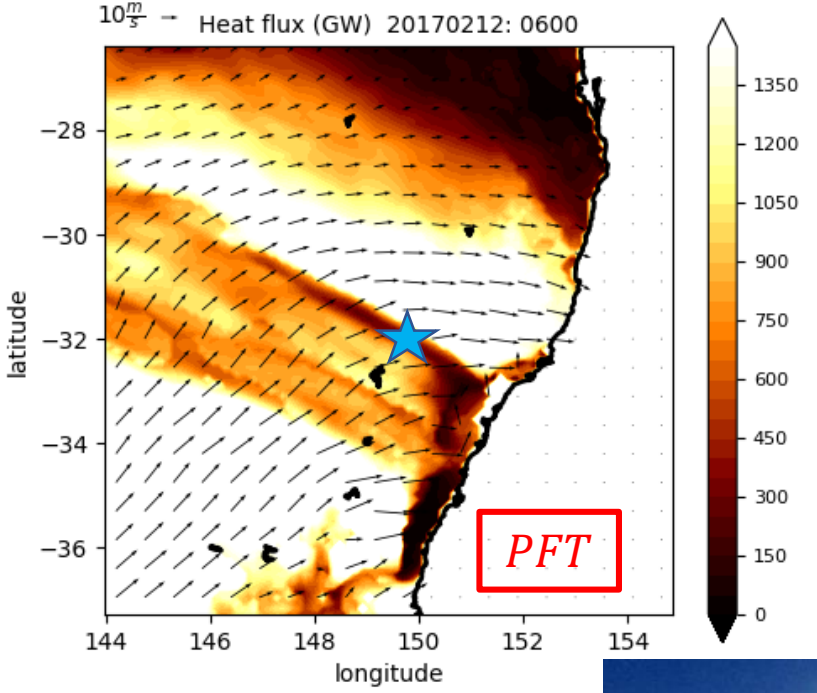


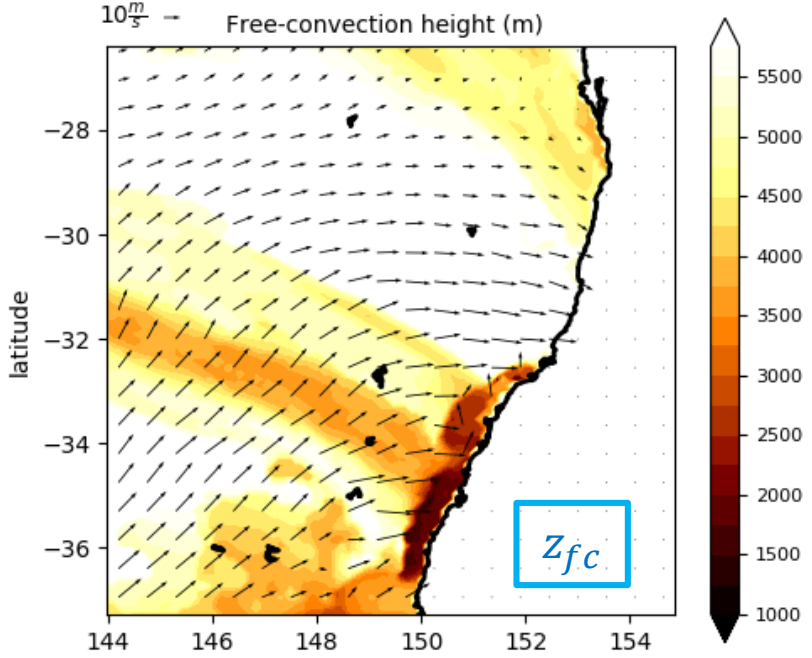
Sir Ivan Fire

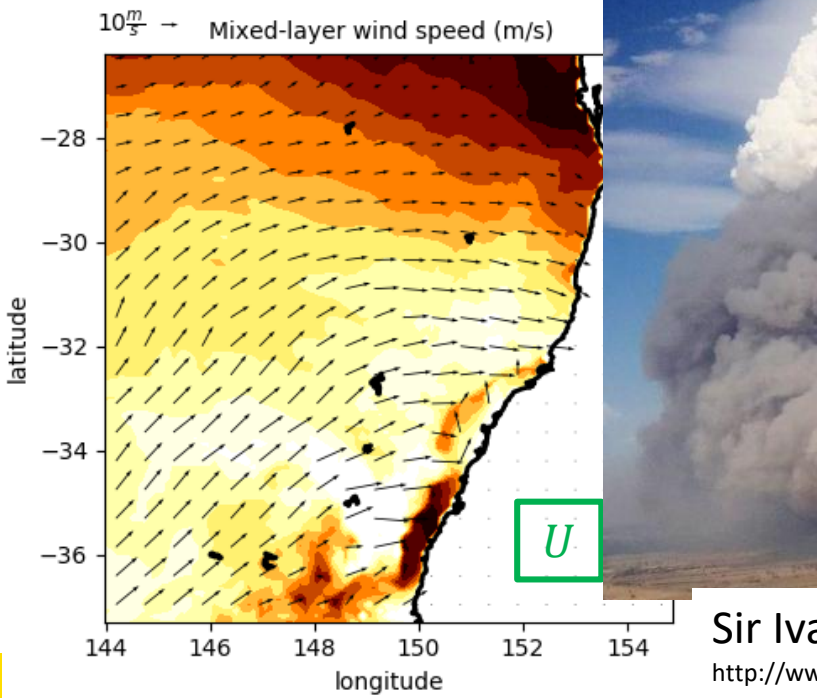
- $PFT = C(z_{fc})^2 U b_{fc}$
- $PFT \sim 200\ GW$

5 PM

- First lightning reported 15 mins earlier
- PyroCb convection ceases 30 mins later







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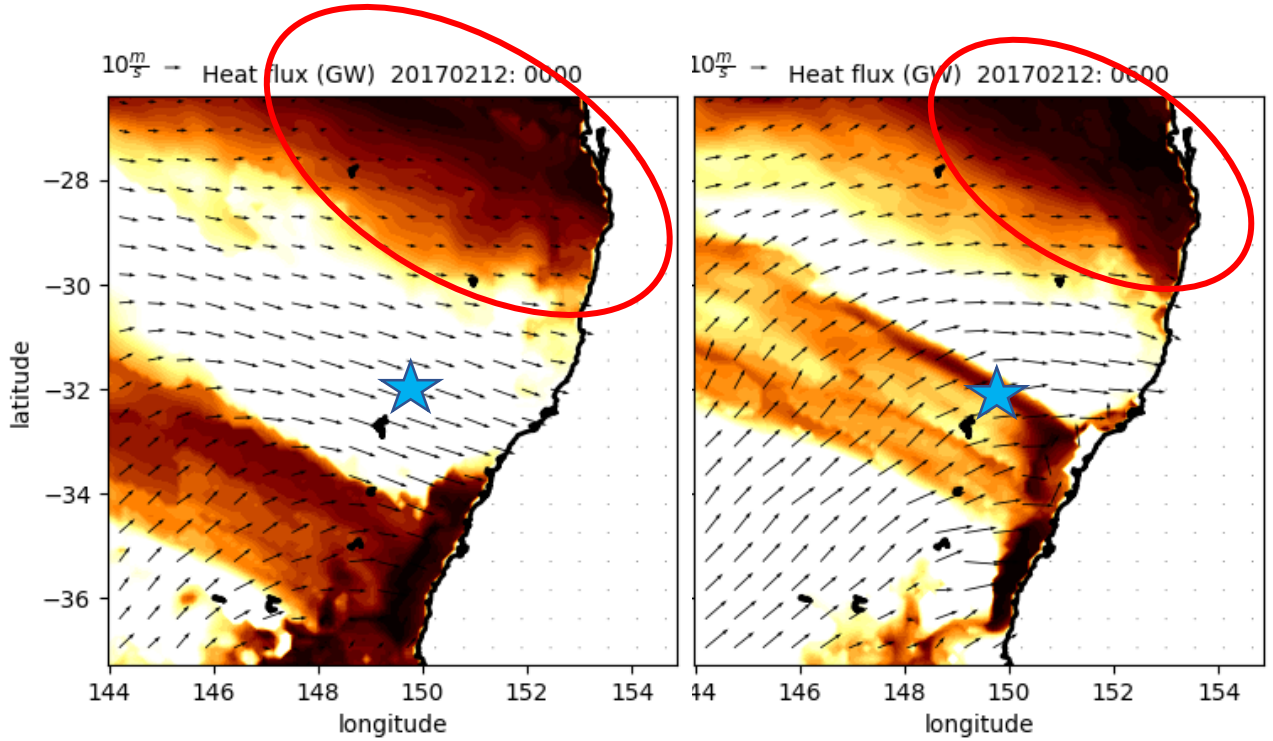
Sir Ivan Fire

- PFT



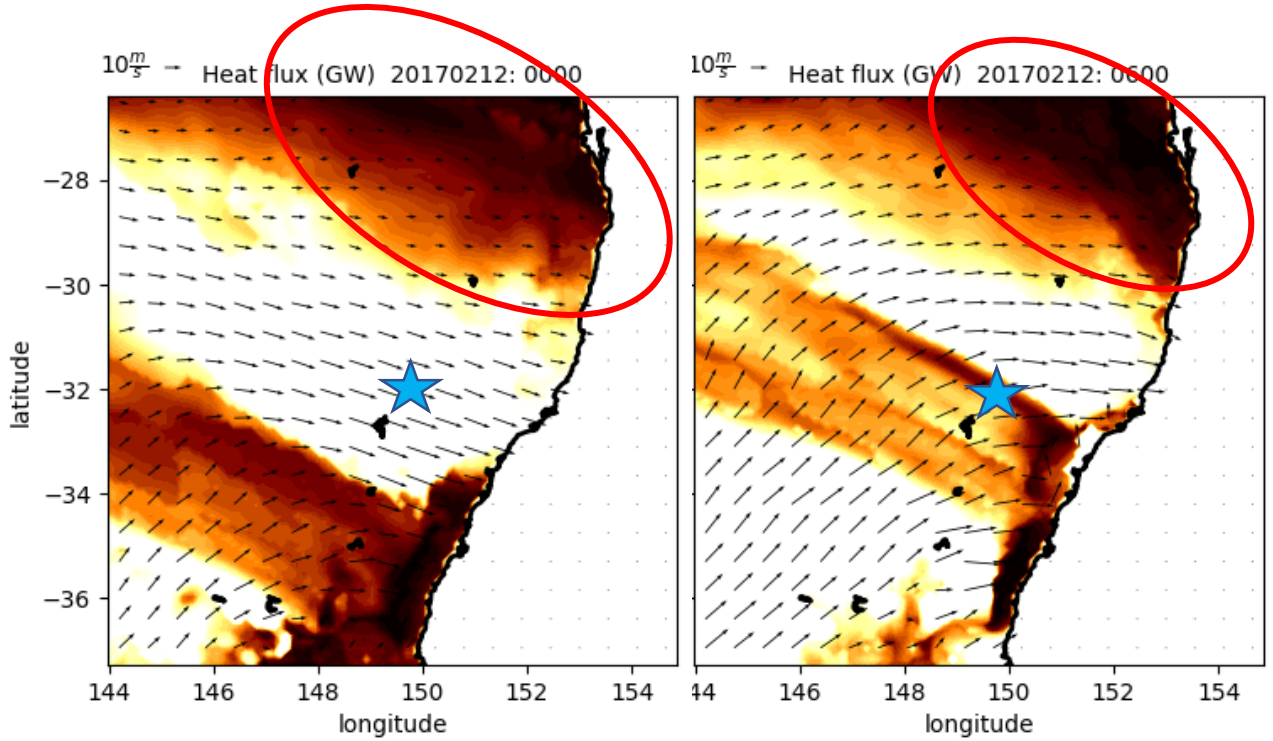
SE Qld/NE NSW:

- False alarm or real threat?

Inglewood Fire 5 Dec 2016: Nick McCarthy

Sir Ivan Fire

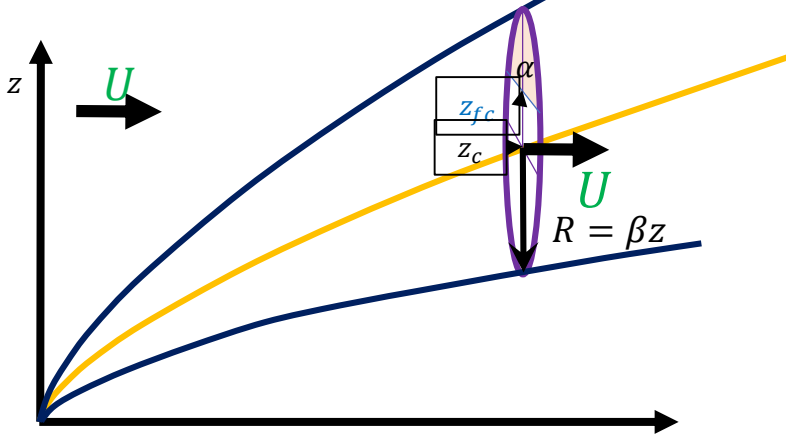
- PFT



SE Qld/NE NSW:

- False alarm or real threat?
- PFT is small when Cb is favourable

Summary



- $PFT = C(z_{fc})^2 U b_{fc}$

- Buoyant plumes:
  - Lose buoyancy as they entrain air from the environment
  - Bend-over in a cross-flow (Briggs Model)
- Use Briggs model to determine PyroCb Firepower Threshold (PFT)
- Useful relationship between PFT and basic variables identified.
- Use pyroCu thermodynamic model to determine PFT ingredients.
- Plot spatial maps of PFT to determine relative pyroCb threat.