Improving the understanding and prediction of fire weather

Graham Mills
Bureau of Meteorology Research Centre

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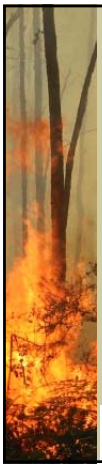

Program A2 : Fire Weather and Fire Danger

"to improve the operational utility of fire weather forecasts and outlooks, by providing better knowledge and understanding of wind, temperature and humidity structures and distributions, on the very short term (1-12 hours), short to medium term, and seasonal through to climate time-scales".

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Program A2 : Project staff

- Graham Mills
- Xin-Mei Huang
- Klara Finkele
- Chris Lucas

Contributors to this talk content

- Evan Morgan (Severe Weather, Victorian RFC)
- Ceri LeFeuvre (Melbourne Uni)

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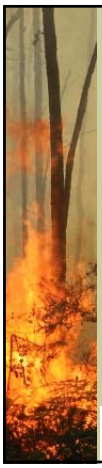

Projects:

- Cool change structures, predictability, and timing
- Moisture forecasting
- Studies of major fire weather events
- Seasonal fire danger prediction
- Developing new products

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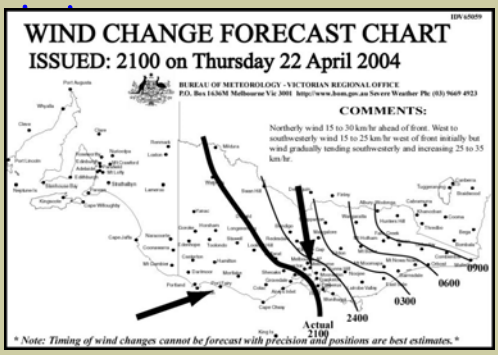
Wind changes – the wind change



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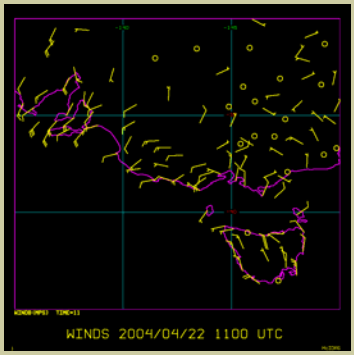
Wind changes – the observations



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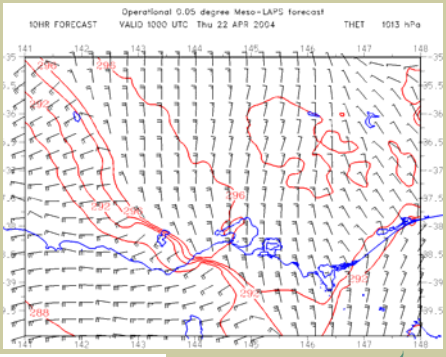
Wind changes – the forecast model



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Wind changes : needs

- Understand structures
- Document forecast performance
- Improve forecast performance
- Combine model and observations to improve nowcasts

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Wind changes – objective verification of model timing

- Aim to determine objective "change time" from time series of observations and from model
- First determine and compare obs timing with RFC verifications
- Find we need to define multiple criteria – direction, speed, gust, humidity
- Low wind threshold 4 m/sec

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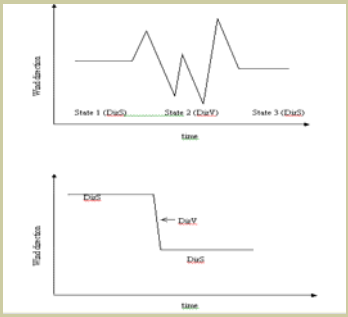
Change model #1



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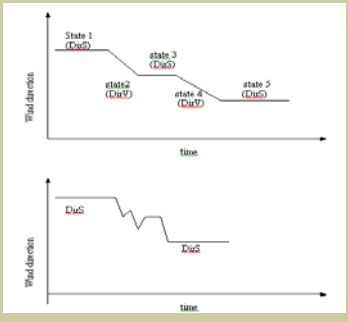
Change model #2



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- Primary output – time of maximum change
- Secondary outputs – start time and end-time of change (Just as important?)
- Compare with RFC verification times at 8 stations

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Table 5.2 Classification of timing differences between objective and subjective methods for Victorian RFC wind change events.

Error Level	< 0.5hr	0.5-2.0hr	> 2hr, RFC in range	< 3hr, RFC out of range	> 3hr, RFC out of range	Total
PTFA	14	2	3	0	0	19
YHSM	7	11	6	0	0	24
YLTV	20	2	4	2	1	29
YMES	17	3	3	1	0	24
YMIA	13	5	5	1	1	25
YMML	29	0	1	0	0	30
YSHT	16	6	4	0	3	29
Total	116	29	26	4	4	180
%	64.44	16.11	14.44	2.22	2.78	

9 RFC verified changes not identified by objective guidance, 6 of these were below the speed criterion.

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Example – simple direction change

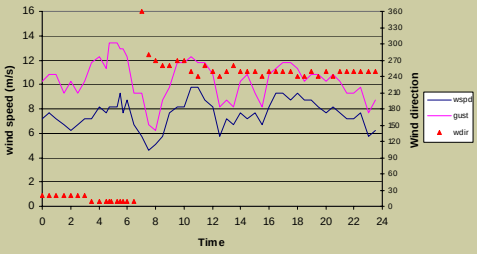

Figure 5.1. Wind speed, gust and wind direction at station PTFA on 11 March 2002. RFC subjective wind change time is 0730LST. Objective method evaluated the wind change from 0600 to 0830 and maximum wind change at 0730LST.

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Example – simple speed change

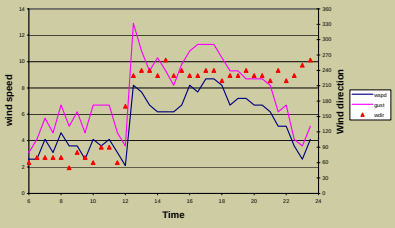

Figure 5.2. Wind speed, gust and wind direction at station YLTV on 20 Dec 2001. RFC subjective wind change time is 1200LST. Objective method evaluated the wind speed change from 1030 to 1330 and maximum wind change at 1230LST.

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Complex direction/speed/gust change at Horsham

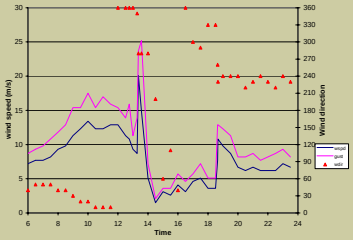

Figure 5.3. Wind speed, gust and wind direction at station YHSM on 15 Feb 2002. RFC subjective wind change time is 1830LST. Objective method evaluated the wind change from 1200 to 2000 and maximum wind change at 1322LST.

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Two (?) changes – Latrobe Valley

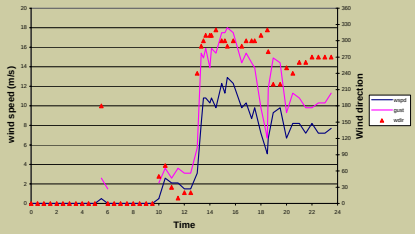

Figure 5.7. Wind speed, gust and wind direction at station YLTV on 18 March 2002. Objective method evaluated first the wind change from 1000 to 1428LDST with maximum wind speed change at 1319LDST, and second wind from 1730 to 2000 with maximum wind change at 1858. RFC subjective wind change time is 1858LDST.

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Opportunities :

- Objective identification – reproducible
- Objective verification of models – identify errors
  - document improvements
- Wind change climatologies – broader than the cool-change conceptual model (mesoscale understanding, geographic differences
- ….. And many more

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Wind changes – verifying forecast structures with radar data (or vice-versa?)

- Wind change 20 January 2004
- Low-reflectivity radar images

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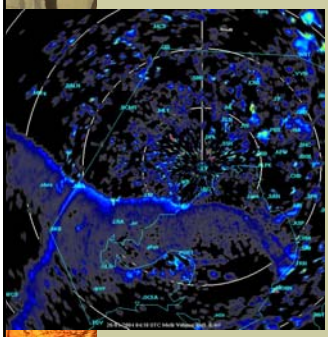
Radar



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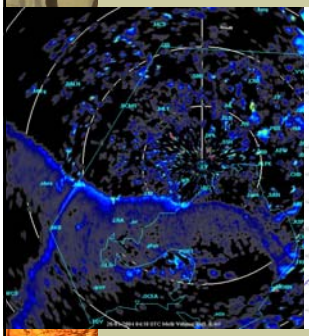
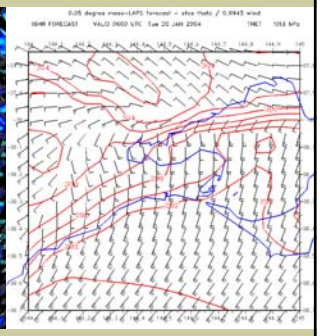
Radar

Numerical model





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Wind changes – verifying forecast structures with radar data (or vice-versa?)

- Triple change structure
- Westward movement of trailing line

- Verifies model structures
- Allows adaptive adjustment of model timing

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Moisture

- Affects FDI via the drought/curing factor term
- Affects FDI via the relative humidity term
- The "dry end" tends to be ignored – it's the "wet end" that leads to rainfall

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Moisture – gridded drought factors

(1) Reproduce current practice, but on a national grid

(2) Develop improved df/fuel state models for input to FDI calculations (cf Knight)

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Gridded daily SDI / KBDI / DF

- Using daily national rainfall analysis and daily temperature analyses a 25 km grid SDI/KBDI/DF covering the whole country is obtained.
- Code gives identical results to that using obs. at point locations
- Rainfall fields represent grid square, not point

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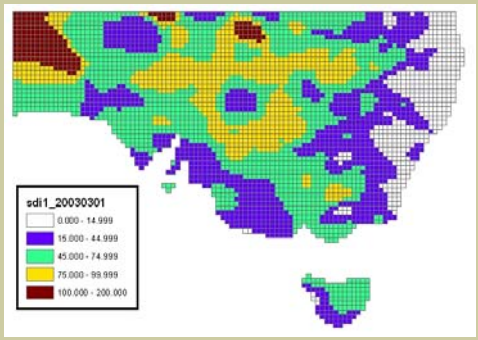
Example - SDI



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Then – gridded FDI forecasts from mesoscale models

- DF from gridded fields
- T, V, and RH from model
- Hourly mesoscale model output

- A DIFFERENT WAY OF LOOKING AT FDI

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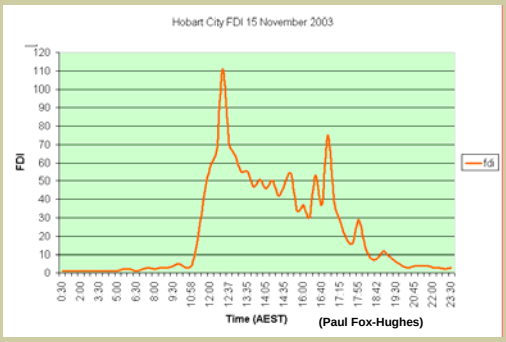
Example – 15 November 2003 - OBS



(Paul Fox-Hughes)

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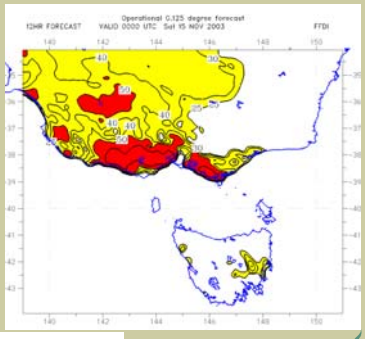
Example – 15 November 2003 - MODEL



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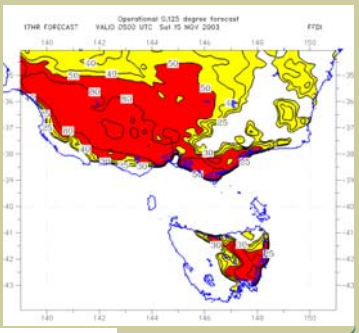
Example – 15 November 2003 - MODEL



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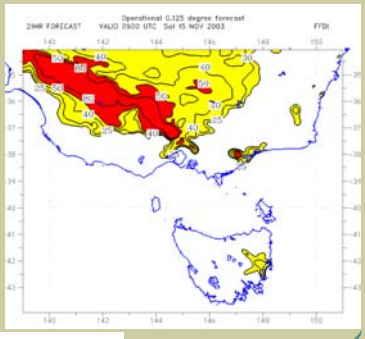
Example – 15 November 2003 - MODEL



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Where with SDI/KBDI/DF/FFDI?

- Trial output this summer
- Change perspective to a field rather than a point – make gridded output the basis of the forecast
- 10km grid for SE Aust
- ISSUE - Bias correction for wind ?
- Gridded grassland curing?

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Where with SDI/KBDI/DF/FDI?

- 30-year climate/normals
- Improved soil moisture/land surface model
- Collaborate with other Program A projects to improve the fuel moisture state specification – ITS CRUCIAL!

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Mesoscale drying episodes - Canberra

- Meteograms show complex evolution of weather elements at Canberra on Jan 18
- Did the fire drive the weather?

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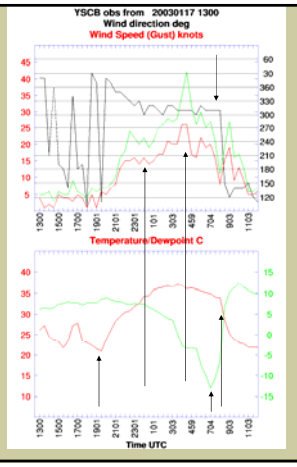

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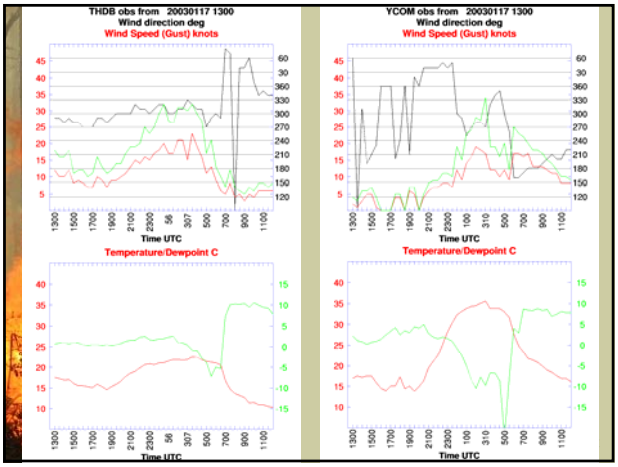

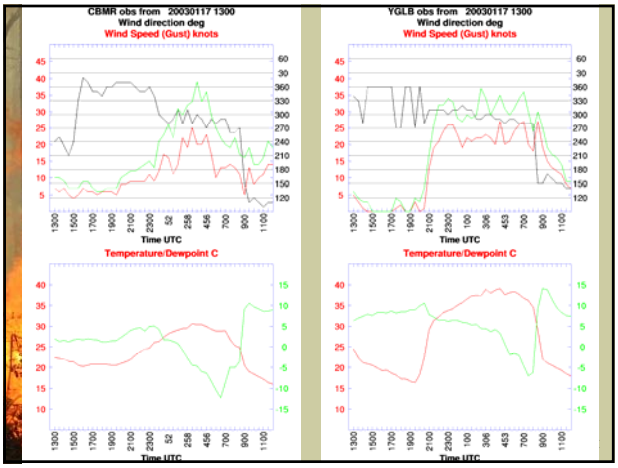

- Need to understand these circulation features
- Need to know how well we forecast them
- Also larger-scale features
  - predicting low nighttime humidity

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New Products - Dry lightning Potential (Ceri LeFeuvre)

- Rorig's phase space:

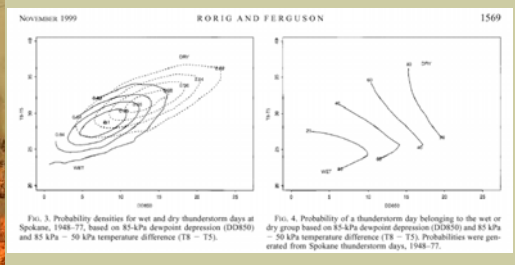

Fig. 3. Probability densities for wet and dry thunderstorm days at Spokane, 1948–77, based on 85-kPa dewpoint depression (DD850) and 85 kPa − 50 kPa temperature difference (T8 − T5).

Fig. 4. Probability of a thunderstorm day belonging to the wet or dry group based on 85-kPa dewpoint depression (DD850) and 85 kPa − 50 kPa temperature difference (T8 − T5). Probabilities were generated from Spokane thunderstorm days, 1948–77.

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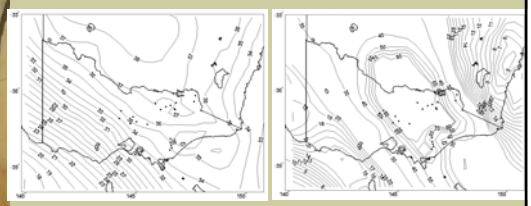
Victorian Alpine Fires, 8th Jan 2003



(a) TD and (b) DPD at 2300 EDST, 7th Jan 2003.

Contours show a large TD (Temperature Difference) indicating instability and a large DPD showing the air is very dry prior to the lightning strikes which ignited the fires.

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Dry lightning – where?

- Proof-of-concept
- Usefulness of same phase-space shows benefits of ingredients-based approach
- Test null cases
- Incorporate in NTFGS
- PhD for Ceri?

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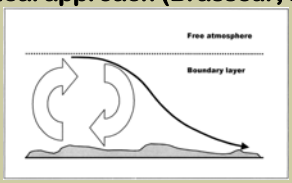
NEW PRODUCTS -Diagnosing gusts from nwp

- Physical approach (Brasseur, 2001)



- Beljaars
  $V_{gust} = V_{mean} + f(u_*)g(H/L)$

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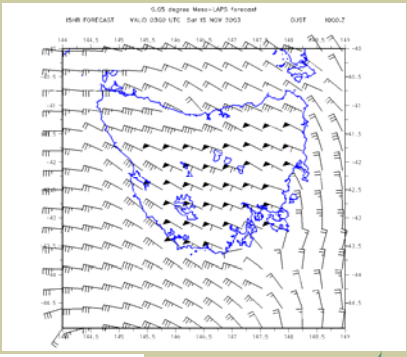
Example – Tasmania 15 Nov 2003



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Studying big events

- Ash Wednesday
  - depth of front important
- Alpine fires breakout
  - nocturnal frontogenesis aloft + gust product
- Canberra fire day
  - complexity of fronts that day
  - outstanding nwp forecasts

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How bad was that day –or, was it really that unusual?

- Ash Wednesday study
- Simple indicator of frontal depth/strength $|\nabla T|_{850}$
- Calculate over 40 summers from NCEP reanalyses
- Order by strength
- Ash Wednesday 3rd highest Feb day

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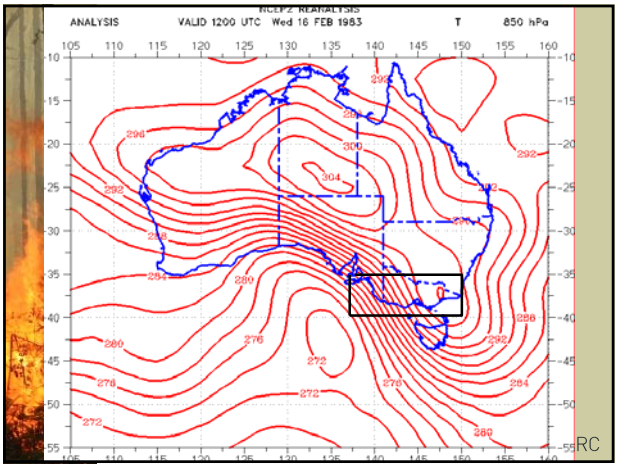

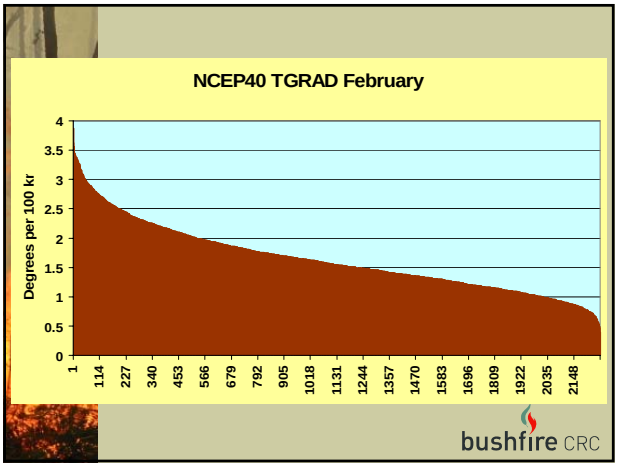

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Tabulating top 30 (Dec-Feb) by TG

Date	Time	TG	TG_x	TG_y	T_{max}	Location
19961225	1200	3.89	2.26	3.16	292.3	Tasmania (6)
19860202	0	3.87	2.92	2.53	290.3	
19721202	0	3.86	3.09	2.30	293.1	Yarra Junction (2)
19780115	0	3.79	3.73	0.68	298.7	Paynesville (7,2)
19701204	1200	3.76	2.85	2.44	296.9	
20030130	0	3.75	3.21	1.94	300.5	Alpine Fires blowout (6)
19771217	1200	3.64	2.20	2.89	292.7	
19860209	0	3.62	2.15	2.91	289.6	
19960119	0	3.62	2.81	2.28	293.5	
19830216	1200	3.55	3.26	1.42	298.7	Ash Wednesday
19650117	1200	3.55	2.59	2.42	297.5	Longwood (1, 7)
19951203	1200	3.55	1.97	2.94	289.5	
19660115	1200	3.53	1.83	3.02	293.4	
19900130	1200	3.53	2.85	2.08	294.6	
19941228	1200	3.53	1.97	2.93	288.8	
20010115	0	3.52	1.88	2.98	295.3	
19800124	1200	3.51	1.66	3.09	288.2	
19800110	1200	3.49	3.40	0.80	293.6	
19790107	1200	3.49	1.08	3.32	294.1	
19900103	0	3.49	1.69	3.05	299.5	132 fires in Victoria (8)
19770212	1200	3.49	3.35	0.95	296.8	Streatham (3)
19820124	1200	3.48	2.51	2.41	302.0	Yallourne (2)
19850114	1200	3.47	2.88	1.92	298.7	Central Victoria (4)
19900103	1200	3.46	1.79	2.96	292.1	132 fires in Victoria (8)
20030130	1200	3.45	2.61	2.26	290.2	Alpine fires blowout (6)
19980226	1200	3.45	2.81	1.99	298.2	SA / Mt Macedon (2,6)
19940107	1200	3.45	1.73	2.98	287.9	
19870202	1200	3.44	2.53	2.33	296.3	
20030107	1200	3.44	2.39	2.48	295.5	Alpine fires Ignition day
19670207	1200	3.44	1.40	3.14	292.8	Hobart fires (5)

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Tabulating top 30 (Dec-Feb) by TG_x

Date	Time	TG	TG_x	TG_y	T_{max}	Location
19780115	0	3.79	3.73	0.68	298.7	Paynesville (7,2)
19800110	1200	3.49	3.40	0.80	293.6	
19770212	1200	3.49	3.35	0.95	296.8	Streatham (3)
19790203	0	3.33	3.31	0.39	293.8	Caroline Forest (9)
19830216	1200	3.55	3.26	1.42	298.7	Ash Wednesday
20030130	0	3.75	3.21	1.94	300.5	Alpine Fires blowout (6)
19721202	0	3.86	3.09	2.30	293.1	Yarra Junction (2)
20020111	0	3.32	3.03	1.34	292.3	
19770212	0	3.18	3.02	0.97	295.6	
19820111	1200	3.44	2.95	1.76	300.8	Central Victoria (2)
19760103	0	3.00	2.93	0.66	297.0	
19860202	0	3.87	2.92	2.53	290.3	
19850114	1200	3.47	2.88	1.92	298.7	Central Victoria (4)
19780115	1200	3.34	2.87	1.70	293.5	Paynesville (7,2)
19980216	0	2.99	2.87	0.80	284.8	
19670106	0	3.10	2.86	1.18	291.9	
19701204	1200	3.76	2.85	2.44	296.9	
19841225	1200	3.33	2.85	1.72	289.9	
19900130	1200	3.53	2.85	2.08	294.6	
19670207	0	3.26	2.84	1.60	296.0	Hobart (5)
19980226	1200	3.45	2.81	1.99	298.2	SA / Mt. Macedon (2,6)
19880114	1200	3.29	2.81	1.72	300.5	
19650118	0	3.01	2.81	1.09	293.2	
19960119	0	3.62	2.81	2.28	293.5	
19680224	1200	3.23	2.79	1.63	297.1	
19810103	0	3.20	2.79	1.56	297.9	Mallee fires (2)
19841225	0	3.37	2.78	1.90	297.0	
19850131	0	3.02	2.78	1.16	287.1	
19731202	1200	3.09	2.76	1.38	290.4	
19680224	0	3.27	2.76	1.76	298.6	

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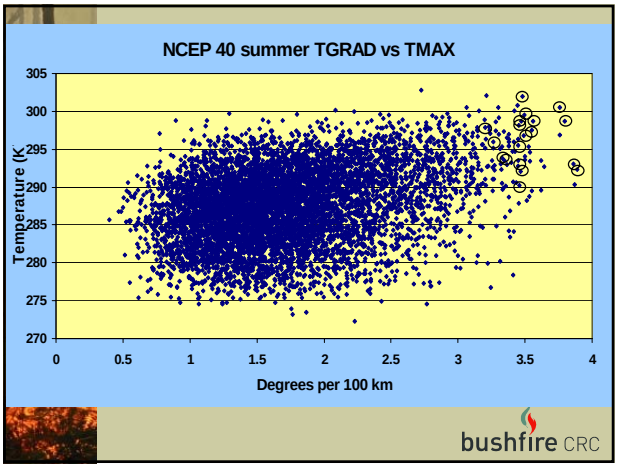

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Potential?

- Expect good medium range predictability – potential alert
- Possible application in seasonal prediction
- Possible application in climate change modelling
- Several caveats:
  - fire data-base
  - variety of mesoscale outcomes
  - only applicable to SE Australia

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Seasonal Prediction - Creating an historical time-series of FDI

- Have high quality rainfall and temperature series (Blair Trewin et al)
- Wind highly problematic
  - use pressure gradients?
- Preparing high quality humidity data set : 1957-2003
- 39 “first tier stations” (5-8 / day)
- 55 “second tier” stations (~2 / day)

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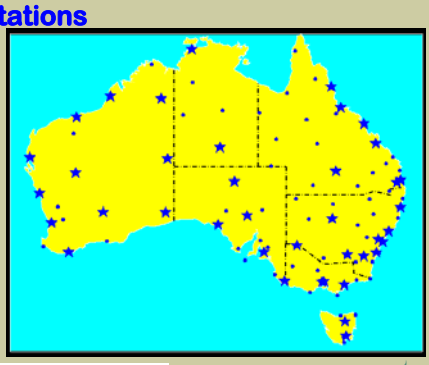
First and second tier humidity stations



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Data issues (1) (eg East Sale)

- Remove ouliers
- Remove thermodynamically impossible data
- Subjective QC – sea-breeze, precipitation etc

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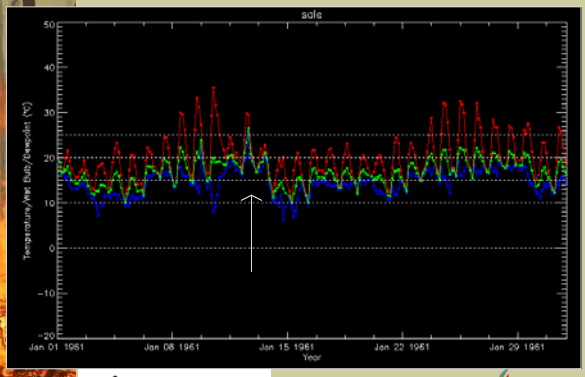
East Sale



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Data issues (2)

- Site changes
- Instrument changes
- Urbanisation

eg Perth

- Site change (twice)
- Instrument change

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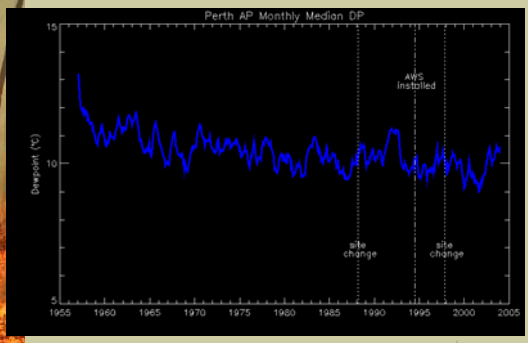
Perth



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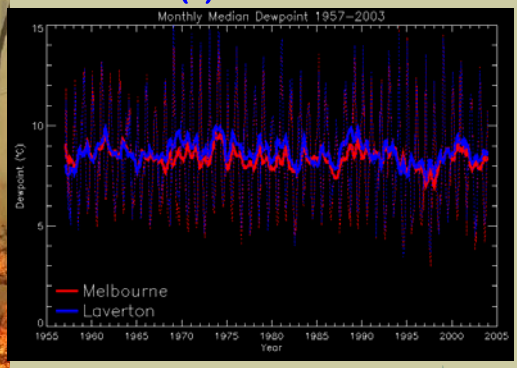
Data issues (3) – Station Biases



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On-going :

- Completion of data qc task
- Development of proxy wind data set
- Investigate controls on surface humidity diurnal cycle
- Combine with data-base of fire history (?) to provide basis for seasonal forecast scheme
  (Linda Chambers)

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Conclusions

- Exciting range of developments
- Steadily make available experimentally, then operationally
- Rigorous verification crucial
- Rich and complex information content a challenge
  - how to communicate
  - how to interpret
  - how to use

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