Weather Extremes in a Changing Climate

Gerald A. Meehl

NCAR
Australian bushfires February 7, 2009: over 240 dead
~1800 houses destroyed, ~200 businesses and other buildings destroyed,
largest natural disaster in Australia’s history
Context of the Australian bushfire disaster:

8 years of severe drought in southern Australia

Record-setting heat wave the week before, three days in a row above 43°C (109°F)

The day of the fires, Melbourne set an all-time record high temperature of 46.4°C (115.5°F) associated with strong high pressure and north winds
Editorial cartoon in Melbourne newspaper the week after the fires indicating Australians know that high pressure in the summer equals extreme heat that is conducive to fires
Is it global warming? There is an awareness in Australia that global warming has something to do with it:

"Face global warming or firefighters' lives will be at ever risk"

PETER MARSHALL

We will be fighting more fires unless we tackle the problem's source.

EAR Mr Braid and Mr Brainier, on behalf of more than 13,000 firefighters and support staff in Australia, I write this open letter to request a review of Australia's fire risk and our readiness to meet future catastrophic events. The fires in Victoria have ripped through towns and suburbs, fells and forests, destroying lives and livelihoods. Adverse rainfall are the sorrowful legacy of the devastation they caused. Never before in Australia's history have we been confronted with such destruction at the hands of fire.

Catastrophe work in conjunction that most of the public try to fix. We often put out fires on the scene. We understand that our job is dangerous by its very nature. However, we are greatly concerned that current federal and state government policies seem destined to ensure a repeat of the recent tragic events.

Consider the devastation in Victoria. Research by the CSIRO, Climate Change and the Environment Council found that a "two metre fireline" scenario will see catastrophic fire events happen in parts of regional Victoria every five to seven years by 2020, and every three to four years by 2050, with up to 50 per cent more extreme danger days. However, under a "high global warming scenario", catastrophic events are predicted to occur every year in Melbourne, and firefighters have been warned to expect up to two significant fire events in 2020. We are being asked to prepare for a massive increase in the number of bushfires by 2050, with catastrophic events predicted as often as every eight years.

The Federal Government’s National Greenhouse Gas Emissions Reduction Plan of 2010. The science suggests that we can no longer rely on the climate of our country. The current climate is far from ideal, and we must act now.

It is clear that we need to act now. The future of our country’s fire services is in this century’s challenges. Our existing resources cannot be expected to cope with the "new global warming" scenario of 2025, 2030, or 2050. We are working on an "extreme" event every five years in our major Victorian country locations under 12 months. Likewise, when the statistics tell us that under a "low warming" scenario, we can expect a "very extreme" event every two years, warning bells must surely be ringing.

Climate change, however, is only one factor. There are many other pressures on our fire services. As cities expand, formally rural areas, and "growth corridors", many volunteer brigades find their own towns and urban areas moving to firefighting. These areas need more resources. And professional firefighters routinely perform duties from rescue to emergency medical response, and we are now required to be part of a new fire response service. The cost of this is not small, and it is clear that we cannot afford to underwrite this.

The real question now must be, whether the public is ready to accept the cost of this, and whether the public is ready to accept the cost of this, and whether the public is ready to accept the cost of this, and whether the public is ready to accept the cost of this.

We are greatly concerned that the royal commission to be set up in Victoria will have a narrow focus to investigate and report on the specific disaster. It cannot have the scope needed to provide an overview of Australia’s fire readiness. Further, we want to ensure that it is not a whitewash, with necessary terms of reference designed to ensure political cover for the Victorian Government.

The proposed Victorian royal commission should be broadened into a broader national inquiry into the nature of Australia’s fire risk and our capabilities to meet that risk. Consideration must also be given to the role of new federal and state governments in urban design and fire management. A significant portion of any solution package must go towards preventing future disaster, as well as rebuilding after the current one.

Finally, now is not the time to play a "blame game" with respect to the Victorian fire. But at the appropriate time, we hope to be able to publicly state the concerns we have been conveying over many years to those in power about the state of readiness of our fire services. A national inquiry would allow Australia to get to the bottom of what happened, but also to work out how to ensure that nowhere in the country will it happen again. We urge state and federal governments to take note of this tragedy and work with us to develop a comprehensive national approach to fire and rescue.

Peter Marshall is the national secretary of the United Firefighters Union of Australia.
How global warming affects extremes: a relatively small shift in the average temperature produces a very large increase in extreme high temperatures and a decrease in extreme low temperatures.
Southern Australia is naturally susceptible to extreme heat and bushfires, but with global warming, there is a shift to drier conditions and warmer temperatures, thus increasing the risk of record-setting extreme heat and record bushfires

Global warming by itself doesn’t cause extreme conditions, but it makes naturally occurring events even more extreme
We quantify possible future changes in weather and climate extremes with **climate models**
Heat Waves

Impacts on human health and mortality, economic impacts, ecosystem and wildlife impacts

(Meehl and Tebaldi, 2004: More intense, more frequent and longer lasting heat waves in the 21st century, Science, 305, 994-997)
Climate models can be used to provide information on changes in extreme events such as heat waves.

Heat wave severity defined as the mean annual 3-day warmest nighttime minima event.

Model compares favorably with present-day heat wave severity.

In a future warmer climate, heat waves become more severe in southern and western North America, and in the western European and Mediterranean region.

Climate model shows an increase in the average number of heat waves per year in the future (top) and an increase in heat wave duration (bottom).

For present-day heat waves near Chicago and Paris, the climate model also simulates large positive 500 hPa height anomalies.
Atmospheric circulation in heat waves becomes more intense for future climate (2080-2099) compared to present-day (1961-1990).

Future change in base state (average) atmospheric circulation due to increased CO2 is conducive to more intense heat waves.
Impacts on Agricultural and Biological Systems related to Frost Days

(Meehl, Tebaldi and Nychka, 2004: Changes in frost days in simulations of twentyfirst century climate, *Climate Dynamics, 23*, 495--511)

Changes in frost days affect:

- Range shifts (latitudinal or altitudinal)
- Change in growing season length
- Water resources (change in snow melt season)
- Earlier flowering; emergence of insects; earlier mating; loss of habitat, shorter hibernation
Changes in frost days in the late 20th century show biggest decreases over the western and southwestern U.S. in observations and the model.
Future changes in frost days from the climate model show greatest decreases in the western and southwestern U.S., similar to late 20th century.
Large-scale changes in atmospheric circulation affect regional pattern of changes in future frost days

Anomalous ridge of high pressure brings warmer air to northwestern U.S. causing relatively less frost days compared to the northeastern U.S. where an anomalous trough brings colder air from north

(Meehl, Tebaldi and Nychka, 2004: Changes in frost days in simulations of twentyfirst century climate, Climate Dynamics, 23, 495–511)
Combined effects of precipitation intensity and dry days contribute to mean precipitation changes

a) Precipitation

b) Soil moisture

c) Runoff

d) Evaporation
Future hurricanes, the indications so far: fewer total, but the ones that form are more intense

(Tropical cyclone tracks from a global 20 km resolution atmospheric model)

(Oouchi et al., 2006)
A typical depiction of daily temperatures on a local newscast (in this case, December 3, 2009 from Denver during a cold snap)
In a warming climate, there should be more record hot weather and less record cold weather.
snow-covered Britain, January 7, 2010
National Climatic Data Center web site archives observed annual daily record high maximum and record low minimum temperatures from weather stations across the U.S. [http://www.ncdc.noaa.gov/oa/climate/research/records/](http://www.ncdc.noaa.gov/oa/climate/research/records/)

As of July 5, 2010:

Since January 1, 2000, 300,912 record daily high maximum temperatures set, and 149,482 record daily low minimum temperatures, a ratio of roughly two to one.

Since January 1, 2010, 6952 record highs and 3885 record lows, a ratio of not quite two to one.

Is there something special about the two to one ratio of record high maximum temperatures to record low minimum temperatures?
Records should decay by $1/n$ over time

In a stationary climate, ratio of record high maxima to record low minima should be roughly 1.0

However, average climate has been warming, and the ratio is now about 2 to 1

A climate model simulation of 20th century climate shows the ratio of record high maxima to record low minima to be about 4 to 1 at present.

This is because:

1. The model has somewhat larger warming in the 20th century than observed.
2. Observed warming has been greater in the western U.S. compared to the east; the model also shows that pattern, but with relatively greater warming in the east than in the model.

Overall greater warming in the model produces a higher ratio compared to observations.
In the future:

Ratio of record high maxima to record low minima about 20 to 1 by mid-century, and roughly 50 to 1 by the end of the century

Even in a much warmer climate, some record low minimum temperatures still occur
Summary

A relatively small shift in the average produces a very large change in extremes—more extreme heat and less extreme cold, and more record high maximum temperatures and fewer record low minimum temperatures.

Global warming by itself doesn’t cause extreme conditions, but it makes naturally occurring events even more extreme.

In a future warmer climate:

Increased heat wave intensity, duration and frequency

Decreased frost days

Increased precipitation intensity, but increases in dry days in some locations combines to produce areas of both average increase (midlatitudes) and decrease (subtropics) of precipitation.

Future hurricanes: indication so far is for fewer total, but the ones that form would be more intense, but better modeling tools needed.

Current ratio of 2 to 1 for record high maximum temperatures to record low minimum temperatures over the U.S. is symptomatic of an ongoing warming of average temperatures; ratio projected to increase as the climate warms: about 20 to 1 by mid-century, 50 to 1 by late century.