A Trans-Tasman Smoke Plume Event, Wairarapa, December 1997

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Abstract
On 3 December 1997 an extensive brown layer was observed in the sky over the southern Wairarapa region of New Zealand. Consideration of the meteorological conditions at the time suggest that this was a case of smoke being transported from large bushfires burning in New South Wales and Victoria, Australia. The significance of a fast-moving coherent plume from Australia to New Zealand is discussed with reference to the possible introduction into New Zealand of industrial pollutants and undesirable biological material carried in the plume.

1. Introduction
It is evident that atmospheric pollutants can remain in a relatively tight coherent plume for many hundreds of kilometres across the Tasman Sea in some strong westerly flows.

This study documents an observation of a brown layer in the sky over the southern Wairarapa, New Zealand in December 1997. Analysis of the meteorological conditions at the time suggest that this was a case of smoke being transported from large bushfires burning in New South Wales (NSW) and Victoria, Australia, to central New Zealand.

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2. 1997 Australian weather and bush fires

Australia’s average temperature for 1997 was 22.0°C, which was 0.19°C above the 1961-90 long-term mean. Weather events, which contributed to the higher than normal annual mean included heat waves across southern Australia during the early, part of the year, and again in November and December across inland NSW; temperature anomalies of up to 5°C above average were recorded in southeastern Australia in February, and again in October, November and December (Bureau of Meteorology Climate Monitoring Bulletins 1997).
Rainfall in eastern Australia was well below average in large areas of South Australia, Victoria, NSW and coastal Queensland (Figure 1). As a consequence, by late 1997, most of southeastern Australia was tinder-dry. Through November and December 1997 more than 400 bushfires (ERRI report 1-336) blazed through many areas of Victoria and NSW, fanned by hot dry winds.

One of the worst was near Coonabarabran, approximately 400 km north-
west of Sydney, where more than 284,000 ha of bushland were destroyed (ERRI report 1-339 and Figure 2). Overall, more than 570,000 ha of land were burned (NSW Rural Fire Service).

![Image](image_url)

Figure 3. View north-west from State Highway 2 near Tauherenikau. Brown-layer bands are visible (marked by arrows) extending west-east across the sky.

### 3. The observed smoke layer

On Wednesday 3 December 1997 at 1730 NZST an extensive brown layer was observed in the sky over the southern Wairarapa region of New Zealand. The layer extended across the sky in bands oriented west-east, moving in an easterly direction. It was estimated that the layer was approximately 4000 m above ground level. Photographs were taken from a position
approximately 1 km south of Tauherenikau (41.1°S, 175.4°E) (See Figure 3).

The layer appeared as a distinct plume, with sharp boundaries, rather than an amorphous cloud. The southern edge was located above Tauherenikau and the northern edge above Clareville, some 25km to the north.

It was suspected that the layer was smoke originating from the large bushfires burning in NSW and Victoria, Australia. An analysis of the meteorological conditions and trajectory analysis follows to support this view.

4. Synoptic situation

Through the days immediately prior to sighting the smoke plume in New Zealand, a strong west to northwest flow prevailed across the Tasman Sea from the surface through to at least 300 hPa (10,000 m above mean sea level). A large depression was centred south of Tasmania at midday NZST on 2 December with an associated trough approaching southeast Australia (Figure 4a). Winds at the surface across the Tasman Sea ahead of the trough were west-northwest of 20-25 knots (Figure 4b); this flow increased with height, and became more westerly, until by 500 hPa (5500 m above mean sea level) a very strong jet existed from eastern Australia to central New Zealand (Figures 4c and 4d). Wind speeds in the jet were up to 65kts at 500 hPa and 90 kts at 300 hPa.

The depression moved rapidly northeast and passed across the south of the South Island during the morning of 3 December 1997. Behind the trough the surface winds backed to the south and from midday on the 3 December the 500 hPa flow was also tending southerly over the western
Figure 4a. Surface analysis 0000 NZST 2 December 1997. Isobars in hPa. Arrow indicates location of Tauherenikau (Kistler et al, 2001).

Figure 4b. Surface wind analysis 0000 NZST 2 December 1997. Main shaft of feather indicates wind direction, full barb is 10kts, half barb is 5kts (Kistler et al, 2001).
Figure 4c. 500hPa analysis 0000 NZST 2 December 1997. Isopleths in decametres

Figure 4d. 500hPa wind analysis 0000 NZST 2 December 1997. Wind feathers as for Fig. 4b, with black triangle representing 50kts (Kistler et al, 2001).
Figure 5. 500hPa analysis 0000 NZST 3 December 1200 NZST 1997 (Kistler et al, 2001).

Tasman Sea. However, the flow further north remained generally westerly (Figure 5).

5.5. Air trajectories

To determine a possible origin for the smoke plume a series of trajectory analyses were computed. Four-day back trajectories were calculated in 1 hour time steps using the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT_4 V4.5) model (Draxler and Hess, 1997; Draxler and Hess, 1998). NCEP re-analysed 6-hourly wind fields were used as input to the model. The trajectory model considers both horizontal and vertical components of motion. The back trajectories were calculated for an end
Figure 6. Back trajectories at 500, 1800, 3000, and 5000m above ground level ending at 1200 NZST, 3 December 1997 over south-

point located over the south Wairarapa district (where the smoke layer was observed), at four different end point altitudes: 500 m above ground level (approximately 950 hPa), 1800 m above ground level (approximately 850 hPa), 3000 m above ground level (approximately 750 hPa) and 5000 m above ground level (approximately 550 hPa), and thus a fairly comprehensive analysis of the air flow through the lower troposphere could be examined. The computed trajectories confirmed a generally west-northwest path at all the chosen levels for air arriving over the lower half of the North Island (Figure 6) on 3 December 1997. The near-surface trajectory, 500 m above ground level, originated over the sea in the tropics near New Caledonia, travelled south through the north Tasman Sea, and can safely be rejected as
a possible carrier of the brown layer. The 1800, 3000 and 5000 m above ground level trajectories originated from the far west of the Great Australian Bight and moved inland over South Australia, northern Victoria and southern NSW before heading directly across the Tasman Sea towards central New Zealand.

Examination of radiosonde soundings from Waggawagga (southern NSW), Cobar (central NSW) and Sydney Airport indicate the potential for the smoke from the fires to be lifted high into the middle troposphere in dry convection and into the strong westerly jet that existed across the Tasman Sea during the 24 hours prior to the smoke being seen over New Zealand (Figures 7a, 7b and 7c). In particular, the soundings from Cobar and Sydney show instability in the lower levels, and all three indicate conditionally unstable conditions to mid-troposphere levels. Winds from about 3000 m above msl are westerly of over 50 knots.

Winds of that magnitude would carry a smoke plume from Australia to New Zealand in 24 hours and the trajectories for the 3000 m and 5000 m heights (Figure 6) cross central New Zealand from inland NSW in just less than 24 hours. The trajectory analyses also indicate that vertical motion on a synoptic scale was small while the air was over the Tasman Sea, and any smoke plume would remain coherent and not be quickly dispersed by atmospheric mixing.

Figure 7. Adiabatic plots of radiosonde ascents from Waggawagga (top), Sydney (middle) and Cobar (bottom), 0900NZST 2 December 1997. Data courtesy of the University of Wyoming, College of Engineering, Department of Atmospheric Science.
The relative short transit time from Australia to central New Zealand (about one day) and the almost straight trajectory of the winds at the estimated height of the brown layer gives confidence to the suggestion that the layer was a smoke plume originating from massive bushfires in south-eastern Australia. There is well-documented evidence (e.g. Collyer et al., 1984) that dust and smoke raised aloft by bush fires and dust storms in NSW can be carried to New Zealand in direct and rapid transfer of air across the Tasman Sea in a similar way.

6. Discussion

The meteorological conditions and trajectory analyses discussed above suggest that the smoke plume observed over central New Zealand on the afternoon of 3 December 1997 originated from massive bushfires in NSW and Victoria, Australia. The plume was carried across the Tasman Sea in a strong westerly flow through the mid troposphere; the very fast transit time and lack of atmospheric mixing kept the smoke in a tight coherent plume rather than in a larger more amorphous cloud covering a huge area. The transport of dust, smoke and other solid particles from Australia to New Zealand is a well documented phenomenon (Marshall and Kidson, 1929, Healey, 1970; Collyer et al., 1984).

In January 2003 many parts of New Zealand were affected by smoke from the devastating fires affecting eastern Australia at that time. There were reports of spectacular sunsets from Auckland in the north to Nelson and Marlborough further south, and the Southern Alps were cloaked in a thick smoke haze for several days (Christchurch Press).

Four-day back trajectories of air arriving at Baring Head (41.4ºS 174.9ºE) in central New Zealand at midnight and midday since 1988 have been gener-
lated using the model developed by Gordon (1986) and six-hourly
analysed wind fields prepared by MetService New Zealand Limited. Nichol
and Man-ning (2001) have carried out an in-depth analysis of airmass
source regions for Baring Head in central New Zealand using the statistical
analysis technique (Dorling et al., 1992) using 10 years (1990-99) of 12-
hourly trajectories. The analysis shows that the dominant transport patterns
show little variation from year to year and that about 54% of the trajectories
represent a general westerly flow; of these, about 11% indicate flow to New
Zealand originating from the eastern seaboard of Australia.

There are some differences between seasons with the summer months
having more trajectories from just north of west (ie from eastern Australia)
than other seasons, coinciding with the time of most risk of fires in that part of
Australia. Bushfires are most likely in spring and early summer in New South
Wales, when low pressure systems near Tasmania bring strong, dry, westerly
winds, and in summer in southern Australia when a series of cold fronts may
approach high pressure systems in the Tasman Sea, bringing dry northwest
winds. All of these situations have the potential to bring smoke from large
fires in south and east Australia into the New Zealand area.

Industry–sourced pollutants from the Australian east coast could also be
transported into the New Zealand area, which could lead to temporary
increases in local area pollution and possibly result in episodes of acid rain
damaging areas of vegetation (Holden and Clarkson, 1986).

The short transit time of the plumes across the Tasman Sea in strong stable
westerly winds shows it is feasible for insect pests to be blown to New
Zealand from Australia, posing threat to native vegetation, and horticulture
and forestry industries. Tomlinson (1973) estimated that suitable trajectories
could occur on an average of 21 days per year. An occurrence involving the
appearance of the grain aphid *Macrosiphum miscanthi* in wheat crops in
Canterbury on New Zealand’s South Island east coast after a strong north-westerly airflow across the Tasman Sea was documented by Close et al. (1978) and further discussed by Turner (1998). Early et al (1995) also identifies a case where Australian Blue Moon and Blue Tiger butterflies appear to have been carried across the Tasman Sea during strong westerlies. There is evidence for a west to east movement of seeds, spores and pollen; pollen from the Australian casuarina tree has been found in peat and surface soils in various parts of New Zealand. The aerial transfer of particulates and biological material from Australia to New Zealand may well increase during El Niño events due to the increase in frequency of strong westerly winds across the region.

Where a plume of air from Australia is brought to New Zealand as quickly as shown in this case study, and where there is very little atmospheric mixing with the plume remaining coherent, biological pollutants uplifted in the airstream can arrive in this country in large numbers into a relatively small area, enhancing a population’s chances of survival.

A more amorphous pollutant cloud, well mixed both horizontally and vertically in the atmosphere, scatters an airborne population and consequently fewer numbers of the biota remain together, decreasing their chances of sufficient numbers surviving to form a new colony.

Forecasting of trans-Tasman migration events is not practicable, except in a climatological sense: we can expect several events every year. However, if it is known that there is a large increase in a particular insect population in southeast Australia, then it may be expected that there is a greater chance of specimens of that species being sighted in New Zealand after periods of strong westerly winds. The insects’ survival here after initial sightings would be subject to other factors, such as the presence or other wise of their usual food and habitat, suitable climatic conditions and to the presence of natural predators or hosts.
References


New South Wales (NSW) Rural Fire Service release, 10 January 1997.


