Impacts of Spring versus Winter Lake Eyre Dust Storms

Application of Online Hysplit Trajectory and Dispersion Models

Lucia Bawagan (#41884157)
University of British Columbia
GEOB 402 Air Pollution Meteorology

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Abstract

Online Hysplit trajectory and dispersion models were used to estimate and compare the behaviour of spring and winter dust storm pathways from the Lake Eyre basin in Australia. Based on a real dust storm that occurred on September 23, 2009, the Hysplit method approximated the spatial extent and persistence of Lake Eyre dust transport within the northeast coast of Australia, and cross Pacific to Indonesia and New Zealand, and was compared to winter dust storm conditions on June 23, 2009. The spatial and temporal extent of these dust pathways suggest significant local and international environmental and human health impacts: although limited by restrained time parameters and lacking information on temperature, humidity, and complex terrain effects.

Introduction

Dust storms are defined by long range, aeolian sediment transport from a source area experiencing meteorologically unstable and high wind velocity conditions, whereby the near surface residence time of transported dust is greater when passing more stable areas. Dust dispersion is thereby characterized by atmospheric stability, vertical wind velocity profiles, and by the migration patterns of synoptic high and low air pressure centers at the local to global scale. In turn, these contribute to the environmental and human health impacts brought about by poor air quality. Dust storms are common in Australia given that dry, loose sediment sources, like the Lake Eyre basin, lack saturation nor vegetative cohesivity and would require minimal meteoric conditions for transport to occur. As "the southern hemisphere's most active dust source, the Lake Eyre basin would often be susceptible to fuelling large dust storms as it is located midlatitude between migrating low pressure and high-pressure belts" (McGowan & Clark, 2008). Particularly on September 23, 2009, an extraordinary dust storm, likely sourced by the Lake Eyre basin, was observed as a red orange haze by Queensland and New South Wales residents (Barlow, 2009). This persisted on the northeastern coast of Australia for three to four days, with its peculiar colour being indicative of iron rich sediment sourcing from the mineral based Lake Eyre basin (Barlow, 2009) (McGowan & Clark, 2008). The impacts reported by locals, with regards to this event mostly involved reduced visibility, sand deposition, and interference with vehicle operations (Barlow, 2009). In addition, other significant environmental and human health impacts associated with long range dust dispersion include increased atmospheric aerosol optical depth, ocean fertilization, enhanced microbial transport, and overall poor air quality.

Data Analysis

The Hysplit (Hybrid Single Particle Lagrangian Integrated Trajectory Model) model estimates the trajectory and dispersion of atmospheric pollutants by computing the path of an individual air parcel from a defined point source at specific release heights. In this case, the Hysplit methods allows the user to predict the meteoric conditions associated with and distinguish between a spring and winter Lake Eyre dust storms. Assuming the same amount of dust is transported from any point within the area of the basin, given the model's point source analysis, the spatial and temporal resolution for modelling Lake Eyre dust trajectory and dispersion were defined by a 6-hour averaging interval within a total 72-hour period at release heights 10 m, 500 m, and 2000 m AGL. The trajectory models were limited to a maximum number of 12 trajectories, assuming a single continuous release of dust every 6 hours to reduce crowding in the trajectory plots. The dispersion models do not include the effects of particle ground impingement, such as deposition, to represent the maximum extent of dust dispersion. Resulting figures were also cross-referenced with news reports accounting for locals having witnessed the red orange haze.

Results

Spring dust storm trajectories reached the Northern Territories, Queensland, and northern New South Wales at heights <1500 m AGL and persisted during the week after the release date, and likewise for dust dispersion. International dust trajectory travelled southeastward to Auckland, New Zealand at increasing heights >4500 m AGL and persisted approximately four days after the release date: from September 23 to 27, 2009. Northwest trajectories travelled across the Timor Sea toward Indonesia at heights <1500 m AGL and persisted throughout the week following the release date. Otherwise, winter dust storm trajectories were restricted inland southeastern Australia, in New South Wales <500 m AGL and persisted throughout the week following the release date: from June 23 to 29, 2009.

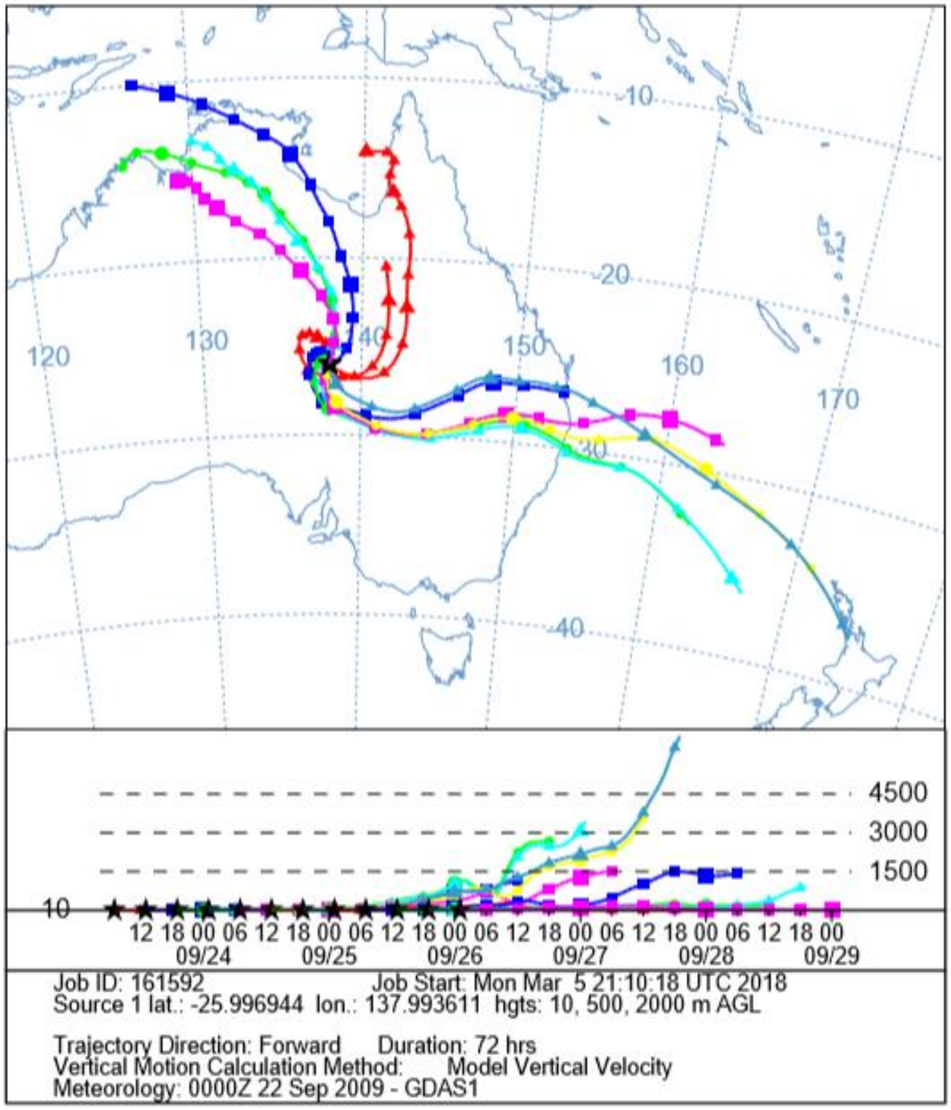

Figure 1. Spring time Lake Eyre dust storm trajectory: September 23, 2009. Represents a high air pressure center above Lake Eyre directing southwesterly winds towards Queensland at heights <1500 m AGL and westerly winds to New South Wales <3000 m AGL. Dust transport reached mid Timor Sea toward Indonesia at heights >1500 m AGL and New Zealand at heights >4500 m AGL within the Hysplit model's time resolution.

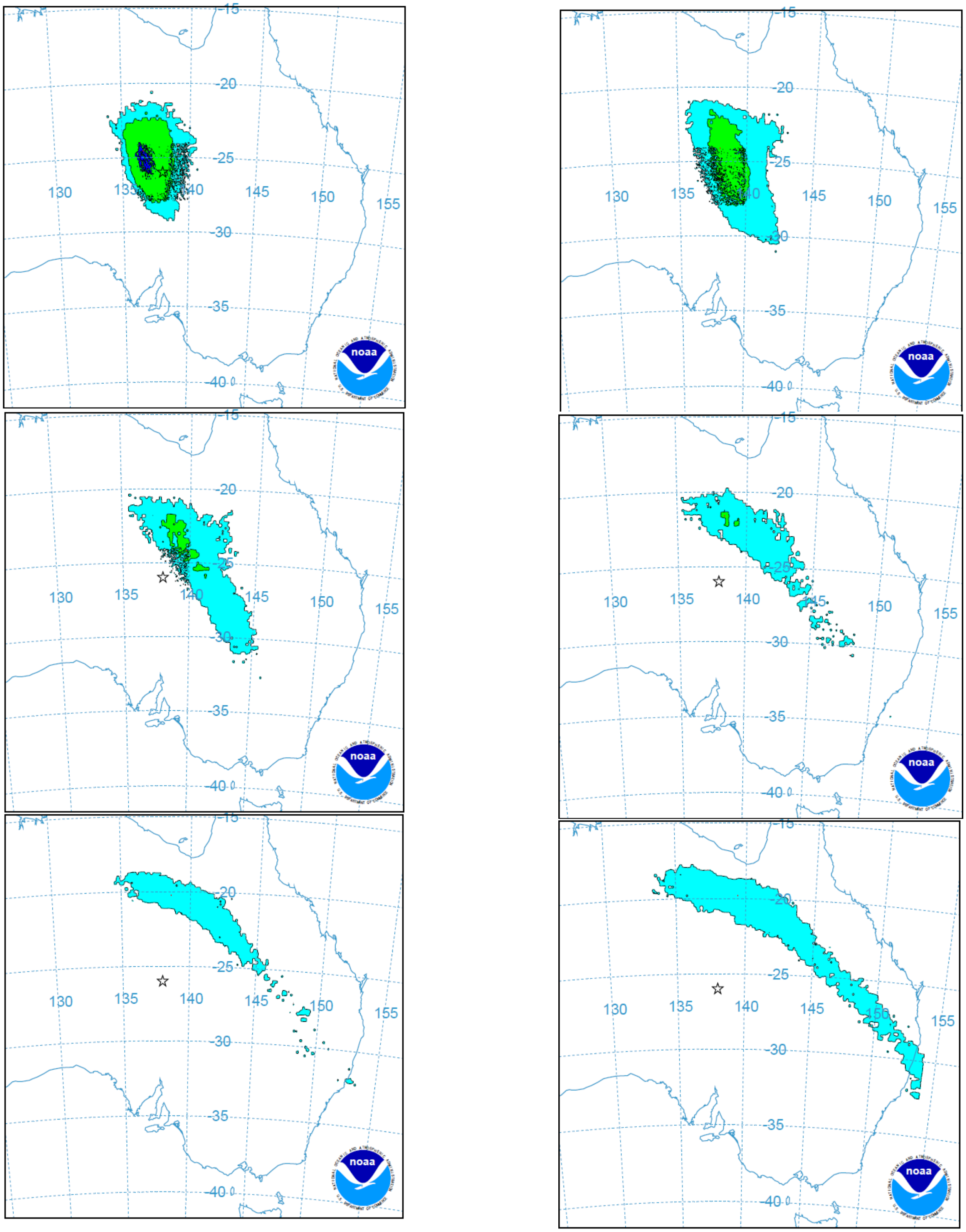

Figure 2. Concentration of spring Lake Eyre dust dispersion. Figures indicate southwesterly winds driving lateral dispersion to the northeast coast.

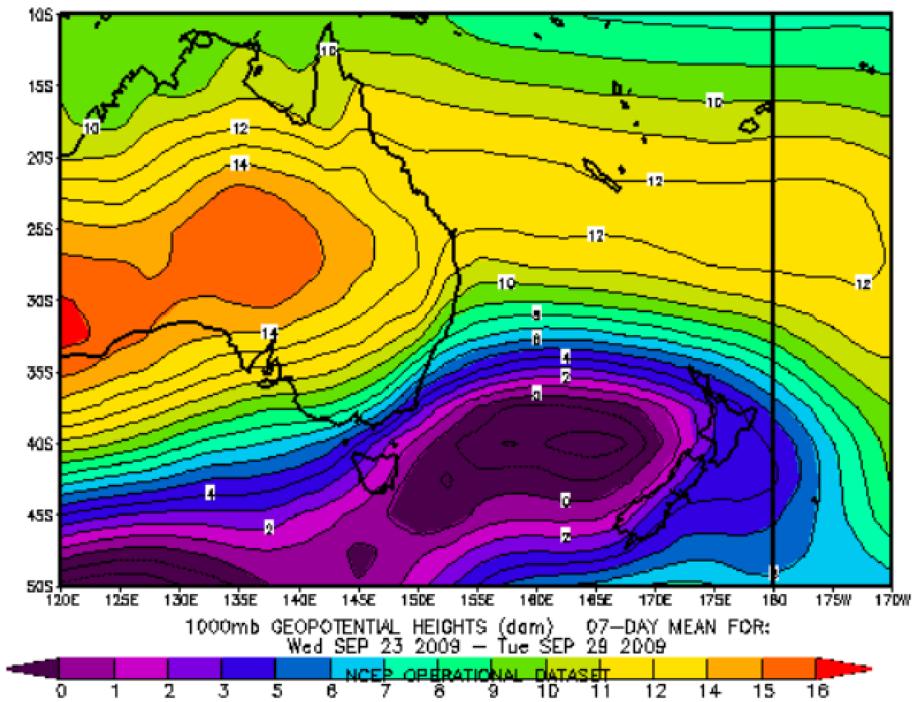

Figure 3. Synoptic weather map for spring time Lake Eyre dust storm measured at 1000 mb. Features a high pressure center driving winds southeastward to a low pressure center at >1000 m AGL (see Fig 1).

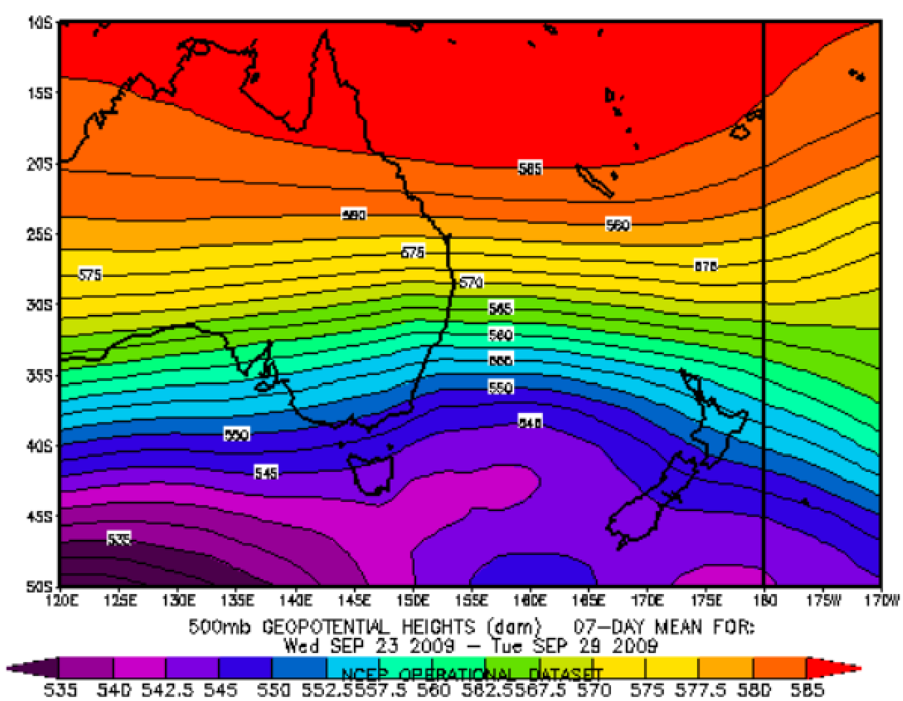

Figure 4. Synoptic weather map for spring Lake Eyre dust storm measured at 500 mb. Features closely packed high pressure bands overlying Lake Eyre bound by low pressure north and south of Australia: indicating steep pressure gradient and significant instability.

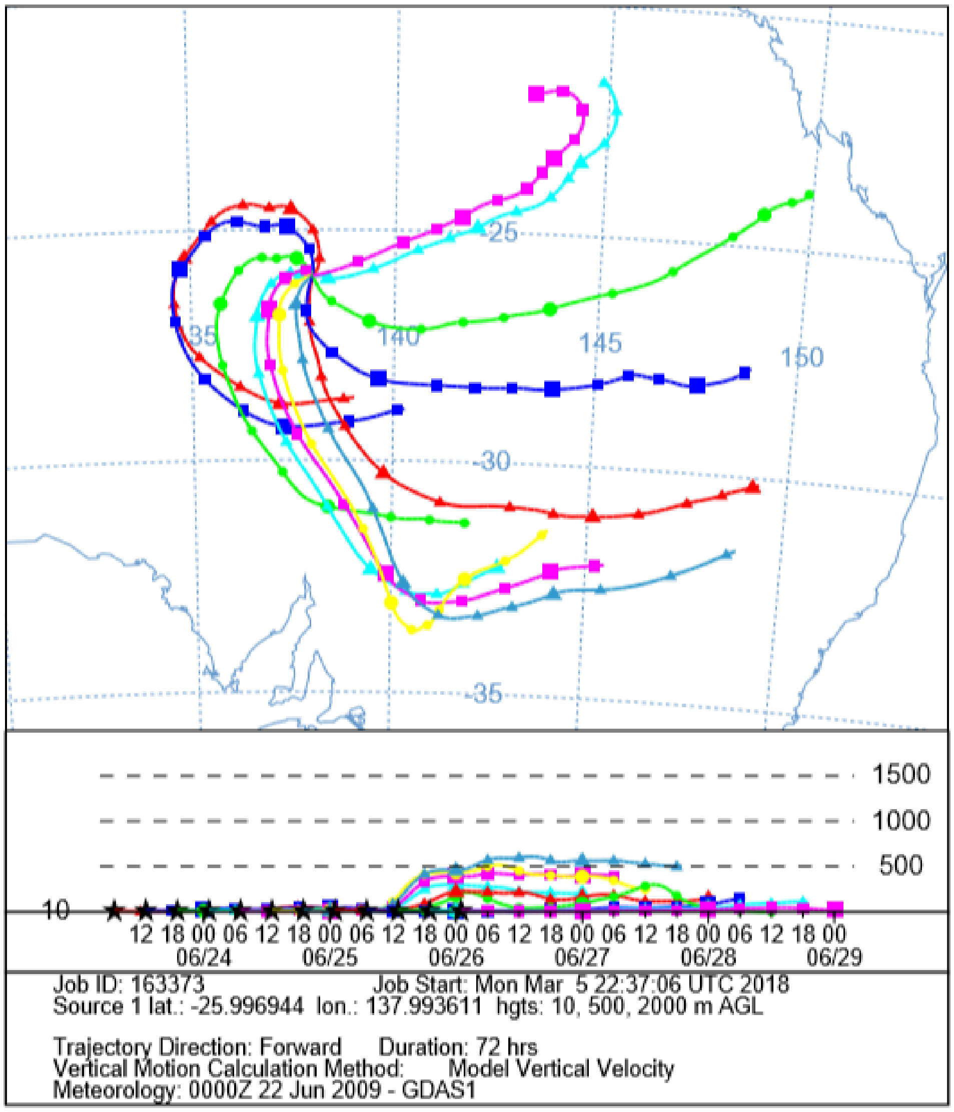

Figure 5. Winter Lake Eyre dust storm trajectory: June 23, 2009. Dust storm trajectory restricted inland Southern Australia and indicates a high pressure center with supressed vertical uplift to <500 m AGL.

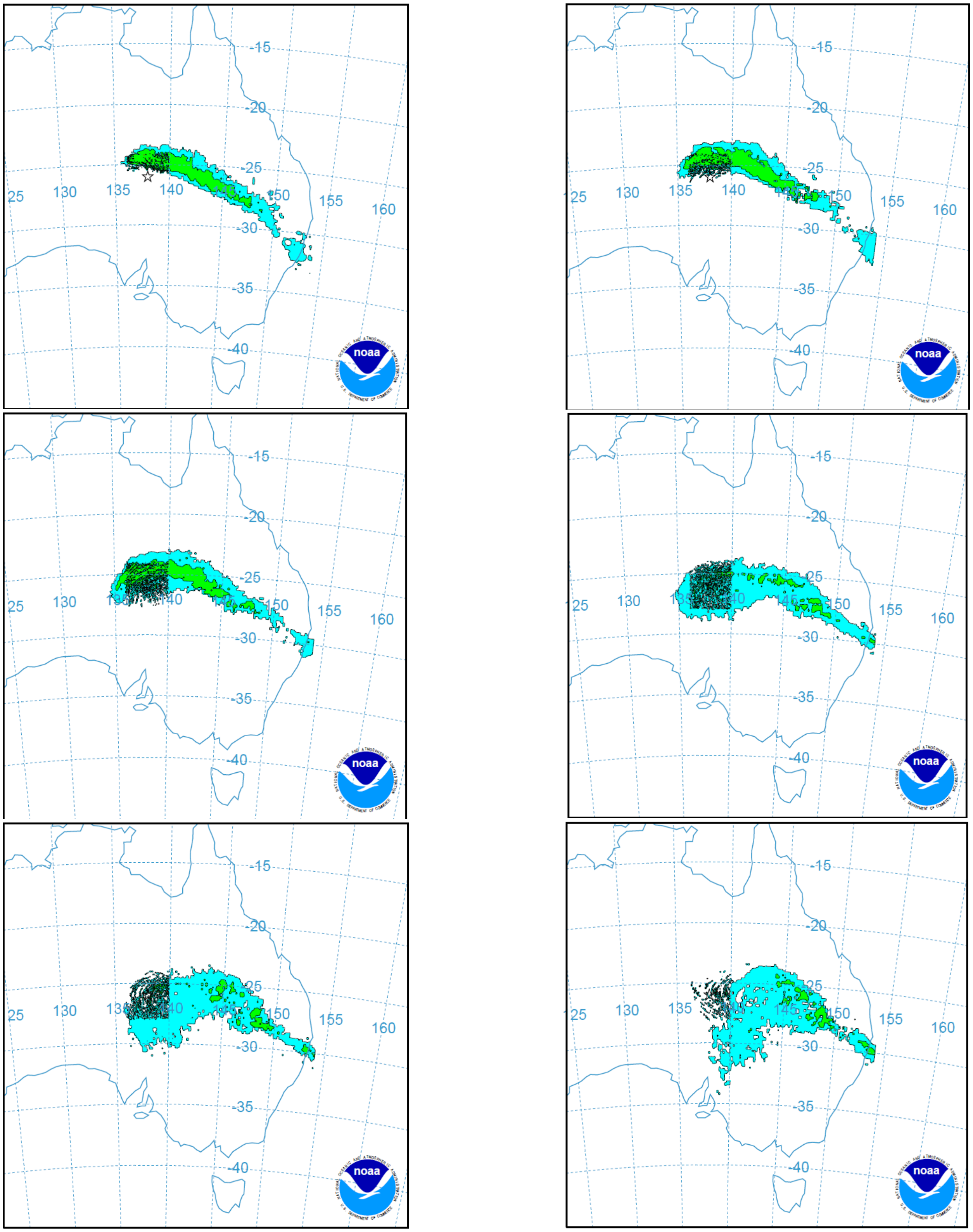

Figure 6. Concentration of winter Lake Eyre dust dispersion. Features locally restricted dispersion within New South Wales via a predominantly southerly wind.

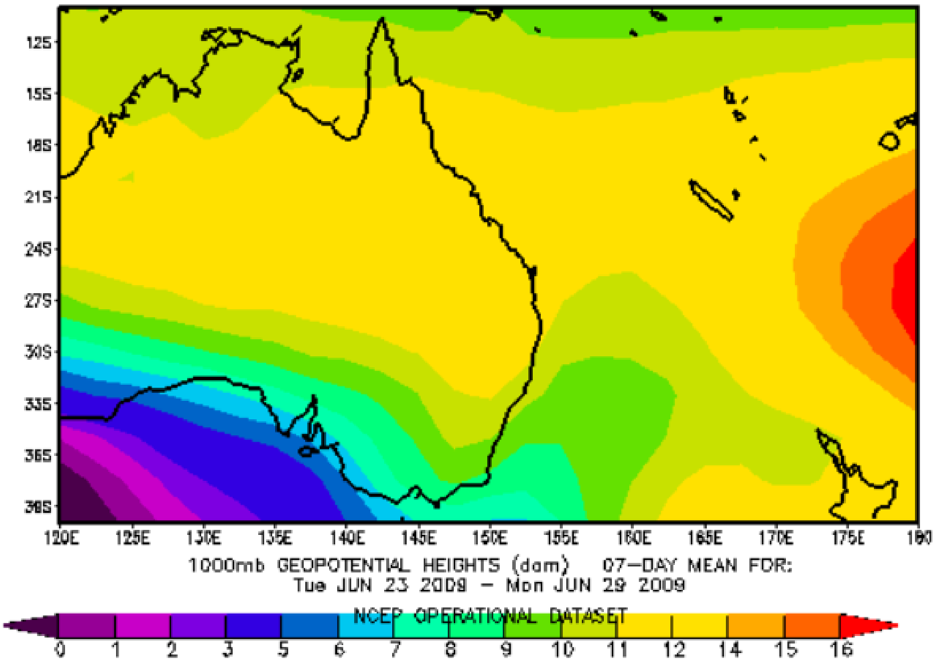

Figure 7. Synoptic weather map for winter Lake Eyre dust storm measured at 1000 mb. Features an exclusive high pressure zone above Australia, restricting winds inland (see Fig. 5).

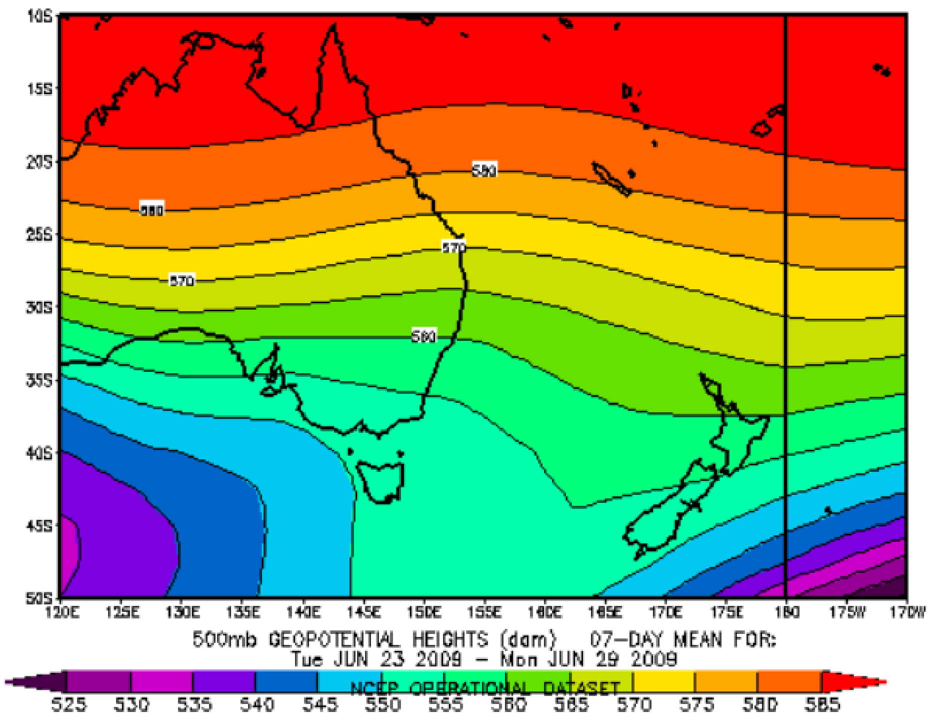

Figure 8. Synoptic weather map for winter Lake Eyre dust storm measured at 500 mb. Features more stable conditions due to less closely packed isobars.

Discussion

The red orange haze observed in Queensland and northern New South Wales on September 23, 2009 was likely sourced from the Lake Eyre basin via a Southwesterly wind that was redirected and dispersed by the counter clockwise flow of an overlying high pressure center above Lake Eyre. The red orange colour of the haze is suggestive of iron rich content from the mineral based sediments of the Lake Eyre basin, typically known for being an active dust source for Australian dust storms (McGowan & Clark, 2008) (McGowan et al, 2000). Figure 2 supports the southwesterly component of the transporting wind by the evident migration of dust dispersion travelling northeastward from the source. Figure 1 and 3 also support this by showing the increasing height of transported dust within an anticyclonic, counter clockwise flow typical of high pressure centers in the southern hemisphere. Such conditions supposedly affected near surface air quality in Queensland and New South Wales by reducing visibility and interfering with vehicle operations (Barlow, 2009). Other significant impacts include the deterioration of local air quality through long range microbial transport, increasing aerosol optical depth that affects healthy carbon cycle and radiative patterns, and initiates iron-induced ocean fertilization (McKendry, 2018) (McGowan & Clark, 2008). Winds that reached the northeast coast of New South Wales at approximately 1500 m AGL travelled further eastward and was likely uplifted, as suggested by the closely packed isobars, taken into the clockwise flow of a low pressure centre aloft, and redirected southeastward toward Auckland at increasing heights >4500 m AGL (see Fig. 1: 09/26/2009 12:00nn, Fig. 3 & 4). With that, Lake Eyre dust would have affected Auckland air quality similarly but near surface conditions would likely be less affected considering that Auckland is farther from the source and transporting winds were observed at much greater heights above ground level. As well, if the Hysplit model considered depositional effects along these dust pathways, the spring Lake Eyre dust storm would have initiated iron-induced ocean fertilization: which enhances algae bloom environments and increased ocean carbon sequestration (McGowan & Clark, 2008). Similarly, winds travelling northwest from the source were shown to reach mid-Timor Sea within the Hysplit's time frame, and although a continued trajectory would have shown Lake Eyre dust reaching southern Indonesia later on, dust deposition causing iron-induced ocean fertilization in the Timor Sea would also be evident (Fig 1). Since dust was not observed at heights >4500 m AGL within the defined time frame of the Hysplit, it follows that there were no observed pressure centers, but rather bands of increasing air pressure northward at 500 mb (Fig. 1 & 4).

McGowan and Clark suggest “non-precipitation cold frontal movement” drive the southwesterly transport of spring Lake Eyre dust storms but the Hysplit model lacks temperature profiles, relative humidity, and the effects of complex terrain to confirm this (2008). Compared to the spring, a winter Lake Eyre dust storm on June 23, 2009 was characterized by southerly winds redirected by the anticyclonic counter clockwise flow of a larger overlying high pressure center with supressed uplift, given more stable conditions as suggested by less closely packed isobars (Fig. 5, 6, 7), and minimal dust would be expected at heights >600 m AGL (Fig. 8). Winter Lake Eyre dust was then restricted inland New South Wales and the associated impacts on air quality would be localized: reduced visibility, vehicle operation interference, possible microbial transport and iron-induced ocean fertilization would be less likely given the limited time frame of the Hysplit, but still possible given an extended time.

Conclusion

The spring time Lake Eyre dust storm observed on September 23, 2009 yielded greater and more far-reaching consequences for deteriorating air quality compared to a winter dust storm on June 23, 2009. That is, spring time dust storms are likely to induce more harmful impacts to environmental and human health for a larger area due to a more centralized high pressure system aloft and more unstable meteoric conditions. Whereas impacts to air quality associated with winter dust storms would be restricted locally.

Works Cited

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