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Short Note

Extreme cold (-69.1°C) in the McMurdo Dry Valleys

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Introduction

The McMurdo Dry Valleys in East Antarctica represents the largest ice-free area on the continent. In 1993, the National Science Foundation (NSF) funded the McMurdo Long Term Ecological Research (MCM LTER) site, which built a meteorological network that included a station on the shore of Lake Vida (LVi) in Victoria Valley (VV) installed in 1995 (Doran *et al.* 1995). This Short Note describes the conditions surrounding the lowest temperature ever recorded in the McMurdo Dry Valleys at LVi and compares them to other nearby meteorological stations.

Methodology

We use data from three MCM LTER stations (LVi, Lake Brownworth (LBr) and Lake Vanda (LVa); Doran & Fountain 2022a, 2022b, 2022c) and the VV station, which was established in 1999 in collaboration with the US Department of Agriculture (Seybold *et al.* 2009). LVi and VV are in the same valley (Victoria), whereas LBr and LVa are in Wright Valley. All stations are controlled by Campbell Scientific CR10x dataloggers. Stations operated by the MCM LTER measure air temperature at 3 m height using Campbell Scientific 107 probes housed in a white radiation shield. Measurements are taken every 30 s and averaged every 15 min. The 107 probe uses a Fenwal Electronics-type UUT51J1 thermistor. At temperatures below -35°C, the error in the polynomial converting millivolts to temperature (°C) becomes significant, and so we apply instead the Steinhart-Hart equation (Steinhart & Hart 1968), which results in a fit that is ± 0.02°C over -40°C to +60°C. Below -40°C, error from the very low voltage *vs* precision of the measurement causes error to be ± 0.12 at -60°C and ± 0.24 at -70°C. A more detailed thermistor discussion can be found in Doran *et al.* (2002).

The VV station measures temperature using a Campbell 109 probe (a Measurement Specialties 10K3A1iA Thermistor) in a white radiation shield at 2 m height. The 109 probe applies the Steinhart-Hart equation directly in the *CR10x* software. VV station measurements are made at 20 min intervals and averaged hourly.

Results

During a long calm period on 14 July 2018 at 01h00 local time (13 July at 12h00 GMT), the LVi 3 m temperature sensor measured a record low temperature for the entire McMurdo Dry Valley meteorological dataset of -69.1°C (Fig. 1a). To put this into context, the average temperature for July 14 from 1996 to 2022 was -47.1°C (SD = 7.0°C). The extreme minimum temperature observed was 22°C below the average temperature, which is three standard deviations lower than the mean.

Figure 1 also shows corresponding wind and temperature trends at the VV, LBr and LVa stations and shows two other extreme cold events in the record for comparison. Figure 1a–c shows that cold periods are regional (synchronous even in different valleys). Another notable feature revealed in Fig. 1a is the warming that follows the record cold, even while winds remained calm at the LVi station. This was observed during other calm periods later in the same winter. This phenomenon also happens at LVa station. LBr experiences much greater wind than the other stations, but the warming observed here is approximately synchronous with the other stations.

Upper-air observations from McMurdo Station, which is 130 km across McMurdo Sound, show the average relative humidity between the ground and 1700 m and indicate a system with greater humidity and clouds moving into the region around the time of the first warming (Fig. 1d). Because the upper-air measurements are made at a significant distance from the ground-based measurements at LVi, they are not expected to be precisely synchronous.

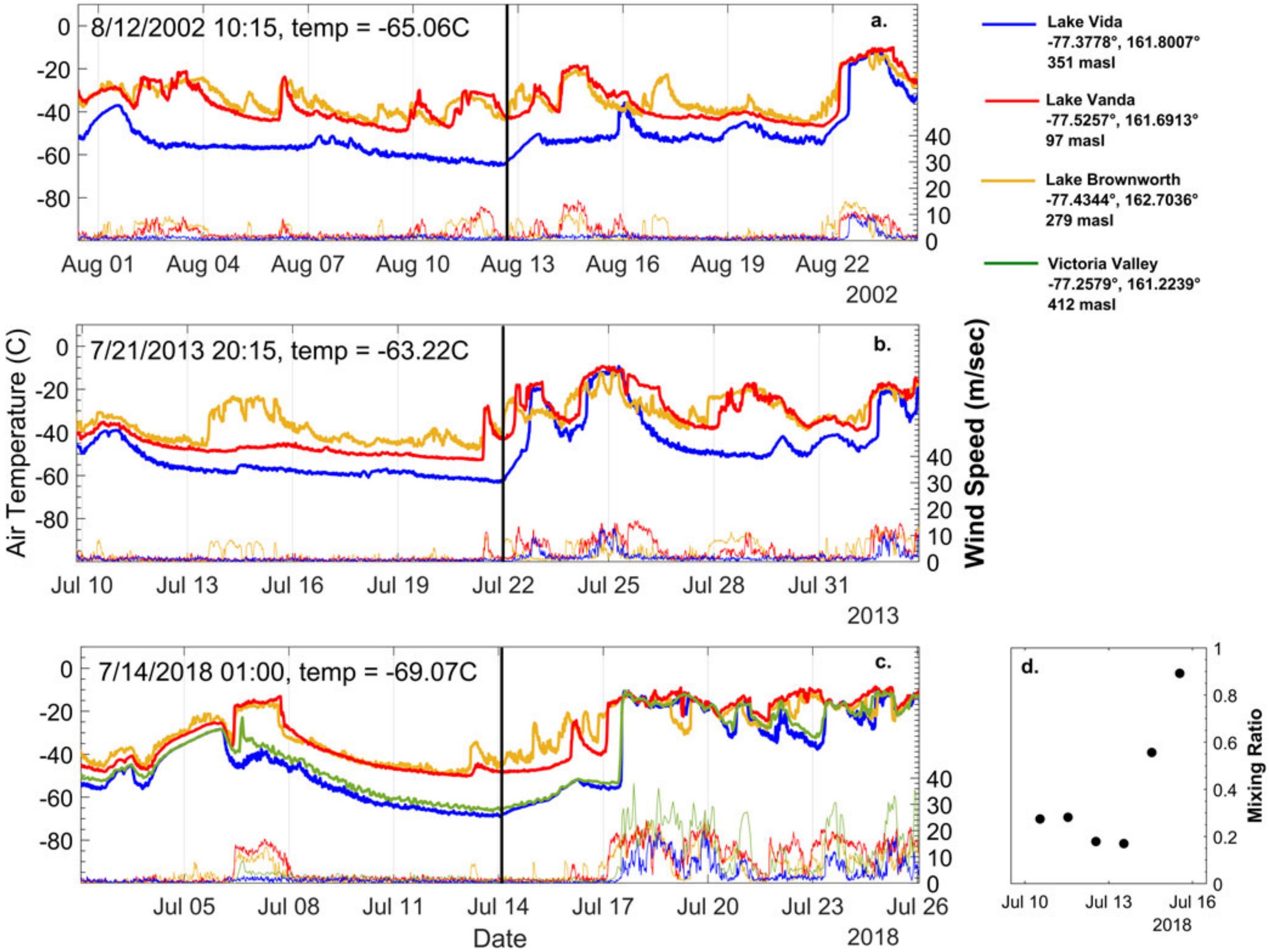

Fig. 1. a. Air temperatures and wind speeds at Lake Vida and three other nearby meteorological stations at approximately the time of the record cold temperature. **b. & c.** Two other cold events (no Victoria Valley data available). Thick lines represent temperature and thin lines represent wind speed. The black vertical lines mark the time of the low temperature. **d.** Average mixing ratios from ground surface to 700 hPa (~2.5 km) height at McMurdo Station during the period of the record cold at Lake Vida. *Data source*: weather.uwyo.edu/upperair/sounding.html. masl = metres above sea level.

The radiative effects at low wind are shown in Fig. 2. We plot the cooling rates (and heating rates) for wind speeds < 5 m/s at LVi and LVa.

Discussion

The LVi meteorological station has previously shown (Doran *et al.* 2002) that Victoria Valley has similar summer temperatures to the other major valleys nearby but winter temperatures that are significantly lower. The low temperatures at LVi result from both radiative and dynamical effects. During the winter, the surfaces of the valleys cool due to the emission of infrared radiation. When the sky is clear, the downwelling infrared radiation from the atmosphere is small and the ground cools efficiently. The presence of water vapour and especially clouds increases the infrared opacity of the atmosphere, reducing the efficiency of the surface cooling. Under windless conditions, surface cooling results in a stable layer of cold air at the valley bottom. Downslope winds disturb this stable layer of cold air. The record cold observed here occurred during one of these windless periods.

It is notable that LVi and VV stations show very similar temperature trends in 2018, providing more confidence in the LVi numbers. VV is consistently a little warmer than LVi owing to its higher elevation and position in the temperature inversion that becomes established during long windless periods.

What is causing the termination of the periods of calm winds and radiative cooling, with regional warming occurring even though winds at the VV and LVa stations

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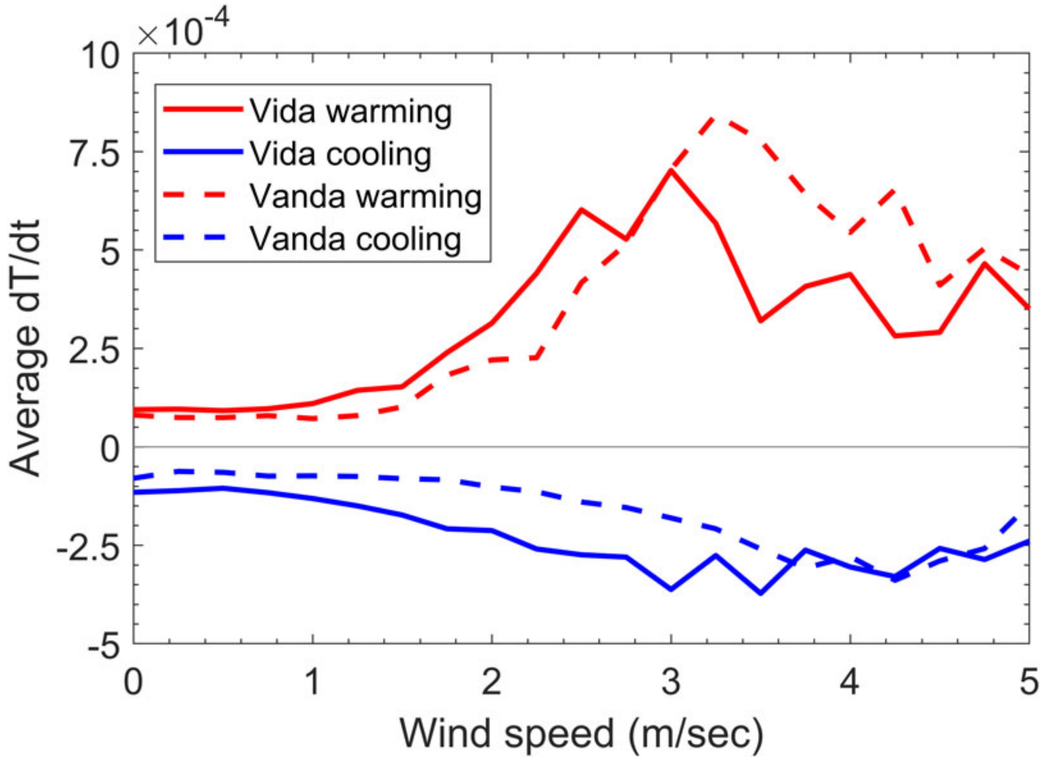

Fig. 2. Average change in temperature over time (dT/dt) *vs* wind speed for Lake Vida (solid lines) and Lake Vanda (dashed lines) meteorological stations. Red lines indicate average positive dT/dt (warming events) and blue lines indicate average negative dT/dt (cooling events) for wind speeds binned by 0.25 m/s intervals. Temperature data were reported every 15 min and smoothed using a moving average over a 150 min window (10 data points). Analysis extends from May through August 2018.

remain relatively calm? We hypothesize that the warming in the absence of wind is caused by synoptic-scale atmospheric systems moving into the region, bringing greater humidity and cloudier conditions. The upper-air data support this hypothesis.

What is clear from the comparison of heating/cooling rates in Fig. 2 is that, during windless conditions, LVi cools more efficiently than LVa. This is probably due to the broader shape of the valley around LVi compared to LVa and hence the decreased role of infrared radiation from the nearby topography.

A comparison of dynamical effects can be made using Fig. 1. We plot the surface temperatures at LVi and LVa for three temperature minimums including the extreme cold event of 14 July 2018. It is clear from this comparison that the onset of windless conditions and the disruption due to increased winds of the resulting stable air layer occur approximately synchronously between LVi and LVa. The LVi data also show synchrony with the VV station.

We conclude that a record cold at the LVi station in VV occurred during a prolonged windless and dry period. The radiative cooling was terminated by an air mass moving into the region that carried greater humidity and more clouds and provided associated infrared warming. Further field data and research are needed to fully understand the details of the extreme cold events at LVi, but the analysis here suggests that radiative effects are what make the coldest temperatures at LVi colder than the coldest temperatures at other lakes.

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Author contributions

PTD and KFM oversaw data collection and analysis. All authors contributed to the writing of the final paper.

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