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Searching for Troposphere-Mesosphere Connections Using the ALO-USU Rayleigh-Scatter Lidar

David K. Moser
Utah State University

Vincent B. Wickwar
Utah State University

Joshua P. Herron
Utah State University

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David K. Moser, Vincent B. Wickwar, Joshua P. Herron | *Physics and CASS, Utah State University, Logan, Utah*

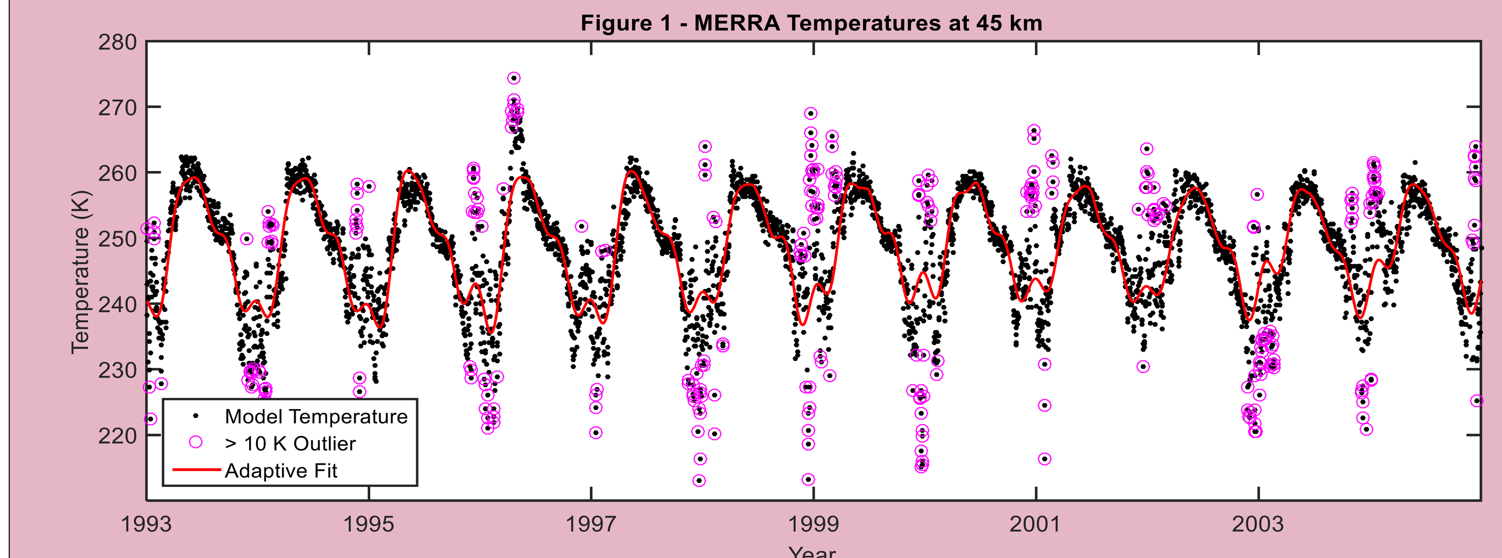
- INTRODUCTION -

The paucity of whole-atmosphere data introduces significant challenges that hinder the study of atmospheric couplings. The mesosphere in particular is a low-information void between the lower and upper atmosphere, which may prevent us from a complete realization of vertical interactions. The Rayleigh-scatter lidar at Utah State University's Atmospheric Lidar Observatory (ALO-USU; 41.74° N, 111.81° W), operated with little interruption from 1993 to 2004, providing a valuable temporal and spatial (45 – 90 km) resource in this realm. When studied alongside a multitude of other atmospheric data sources, possible unforeseen connections or insights may result. In this study, an adaptive fit is applied to near-stratopause temperature data from the lidar and several assimilative models to identify simultaneous abnormal changes. A possible connection with tropospheric events is investigated as an example of future efforts that can be made to synthesize similar environmental figures where available.

- FINDING OUTLIERS -

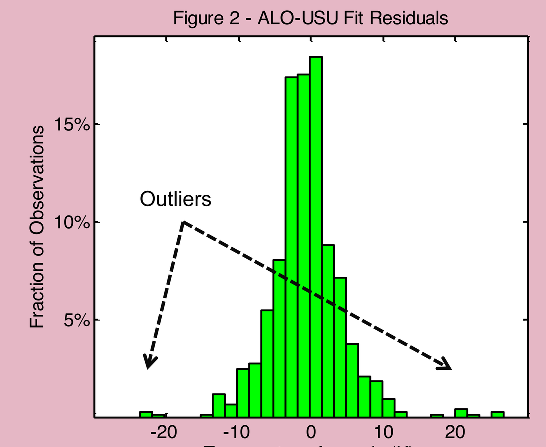
A Levenberg-Marquardt algorithm featuring a 10-paramater, 3-year moving fit was applied to lidar and model data to predict temperatures at 45 km. Temperature outliers were defined as any residual of magnitude 10 K or more. Figure 1 below illustrates the method applied to MERRA data.

Figure 1 - MERRA Temperatures at 45 km



The method yields a fairly normal fit across both reanalysis models and observational data (Figure 2). The majority of outliers, both positive and negative, occur during the winter. Dates with corresponding outliers were identified for further investigation, with ECMWF showing the most agreement with observations from ALO-USU.

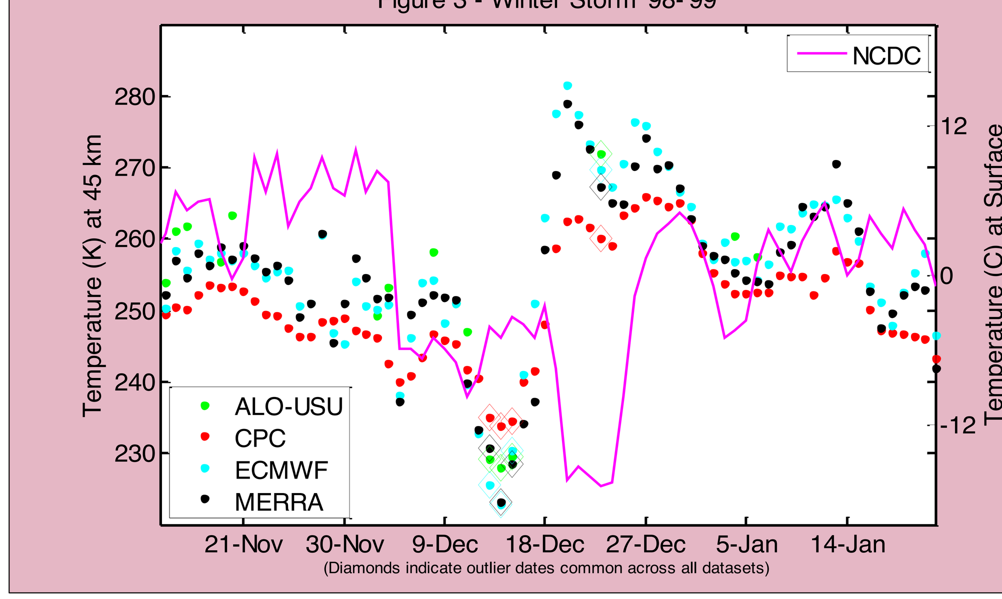
Figure 2 - ALO-USU Fit Residuals

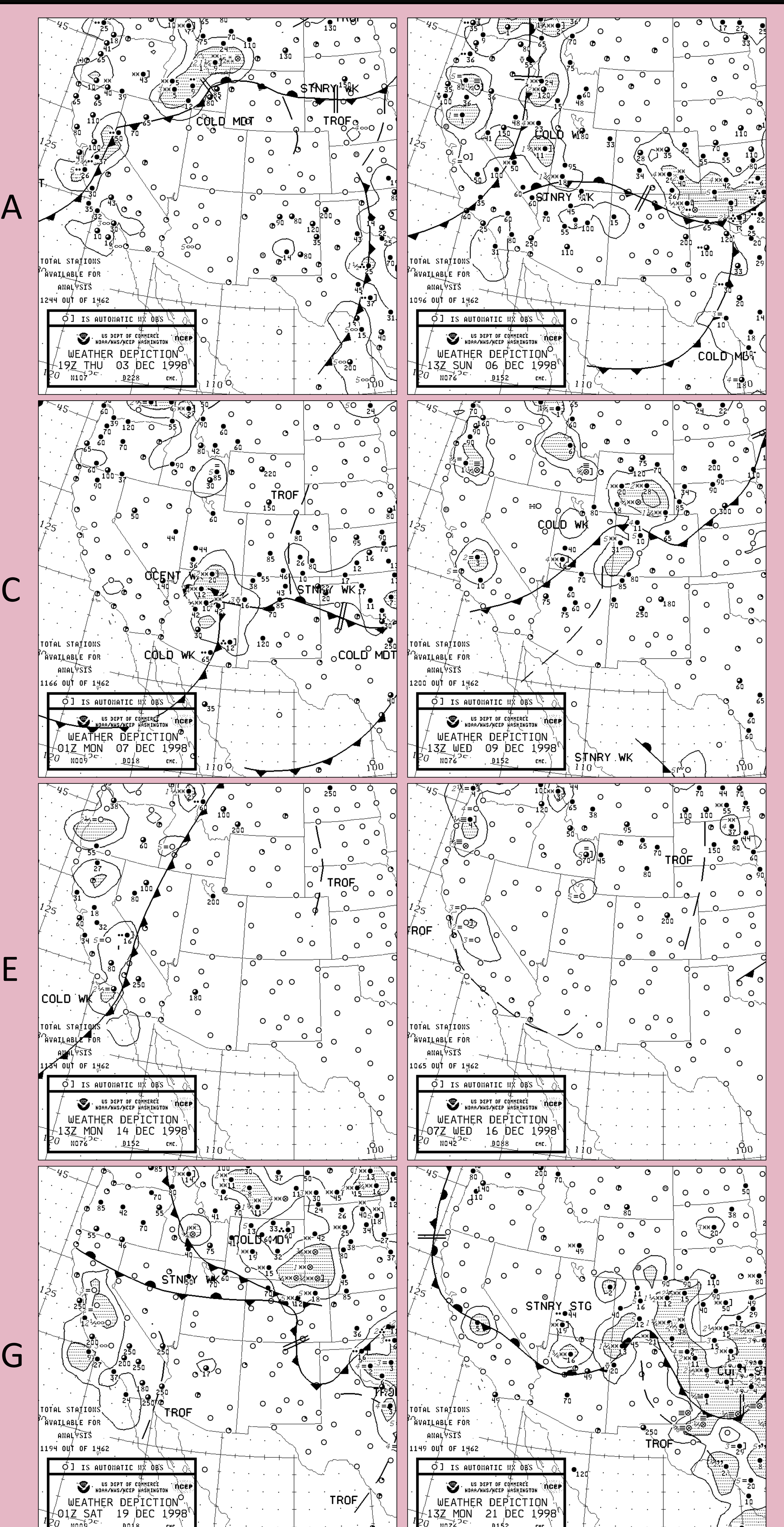


- SEARCHING FOR TROPOSPHERIC CONNECTIONS -

A notable cluster of temperature outliers took place in mid-December, 1998. Four days demonstrate significant departures from expected behavior in all 3 models as well as lidar observations. Comparing ground-level weather records obtained from NOAA's National Climatic Data Center (NCDC) with 45 km temperatures (Figure 3) reveals an upper-level oscillation (half-period ~1 week) in close temporal proximity to plummeting surface temperatures. Chart A shows a cold front (CF in text; COLD on charts) approaching from the NW and a stationary front (SF in text; STNRY on charts) near ALO-USU's location. This system's passage brought snow and a dramatic drop (~15 °C) in surface temperatures over 24 hours. Soon following is a different, weaker CF (Chart B) that merged with the SF in the presence of a trough (Chart C). A final weak CF passed through the region on the 9th (Chart D) before the first outliers. These latter fronts may have contributed to the 45 km oscillation, but the initial system is more likely to cause significant vertical propagation. Another possibility might be a planetary wave associated with the CF passing through during the negative phase of the oscillation (Chart E), although it has no accompanying large temperature drop. During the upswing of the oscillation a persistent trough settled over the western US (Chart F). This was disrupted just before the positive peak by a weather system (Chart G) bearing many resemblances to the first; i.e., frozen precipitation with a CF & SF in close proximity, which merge into a single, larger SF shortly after passage (Chart H). The lack of discernable matching upper-level oscillation in Figure 3 does not necessarily rule out its existence, since phase cancellation could provide for the observed stabilization of 45 km temperatures. Two other dates (1/20/97 and 2/21/01) were inspected briefly, and while the prominent oscillation examined above is less distinct, the 1-2 week time frame preceding both events also features moisture-bearing frontal passages associated with ~10-15 °C drops in surface temperatures over short time frames. The presence of precipitation as a common factor might suggest a relationship with the storms' latent heating effects. The 12/98 event's more impressive temperature oscillation could be due to reinforcing wave-wave interactions, an idea corroborated by the second storm passage's simultaneity with the period of fastest change in the upper atmosphere. Similar effects could also account for the less remarkable oscillations that follow the other dates of interest.

Figure 3 - Winter Storm '98-'99





- SUMMARY AND THE FUTURE -

Coupling effects between the lower and upper atmosphere can be better understood through more exhaustive synthesis of data from multiple sources. By relating ALO-USU's observational data to various models and records covering the troposphere and stratosphere, a relationship between storm fronts and near-stratopause temperatures begins to take shape. Coupling processes involved could be greatly resolved by inspecting conditions at intermediate altitudes. Furthermore, events with obvious connective activity could be investigated upward to 90 km using ALO-USU data to show further propagation, where a connection could possibly be made with lower thermospheric phenomena in upper-level models.

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