AN EXAMINATION OF ATMOSPHERIC LIDS DURING COPS

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Abstract: The understanding of the nature, origin and prevalence of atmospheric lids is low. There is, therefore, an opportunity to contribute significantly to this area of meteorology - this is the goal of this work. The context for this paper is the Convective and Orographically-induced Precipitation Study (COPS). The COPS observational campaign, which was undertaken in 2007, was based around the Black Forest region with the aim of improving precipitation forecasts in low mountainous regions. However, the project also represents a great data archive with which to analyse isolated features, such as atmospheric lids. In short, lids play a vital role in the development of convective storms. For example, evidence from the Convective Storm Initiation Project (CSIP), which was run in the UK in 2005, has shown that lids are important not only in determining whether a storm occurs but also when and where they develop and how intense they are – sometimes, counter-intuitively, they appear to increase the intensity. This extended abstract is intended as a brief overview of the previous literature on lids in order to place the work presented at ICAM-2009 in the wider scientific context.

Keywords: *inversions, capping, convection, convective inhibition, stability*

1 INTRODUCTION AND TERMINOLOGY

The term *lid* is often used in the context of atmospheric science. It is a useful concept, in addition to measures of lifting, when analysing or forecasting the development of convection. Therefore, it comes as little surprise that one of the first uses of the term in the scientific literature was in the description of the conditions leading to the severe storms in the Midwestern United States (Carlson and Ludlam 1968).

Why are atmospheric lids important? In the absence of the lid, the convection that develops is often widespread but shallow, unless the profile is unusually unstable. The presence of a lid can allow the lowest levels of the atmosphere to accumulate heat and moisture, creating the potential for deep convection. Release of this potential can occur at selected points along the capped region when there is sufficient boundary-layer forcing (i.e. convergence or orographic uplift). Alternatively, the lid may be weakened by large-scale uplift, or there may be a combination of the two effects. This rather complex interplay between the lid and deep convection is one reason why *convective available potential energy* (CAPE) by itself is not a good predictor of thunderstorm magnitude (McCaul and Weisman 2001).

The key feature of a lid is its *stability* (i.e. increasing potential temperature with height). Once a thermal is initiated in the atmosphere it will only remain buoyant whilst it is warmer than the air around it. Lids, or stable layers, are, therefore, very often associated with temperature *inversions* i.e. where the vertical temperature gradient changes from cooling with height to warming. Indeed, the top of the atmospheric boundary layer, which traps the turbulence that is induced at the surface, is frequently referred to as the *capping inversion* and, similarly, lids are often referred to as *caps*. However, a temperature inversion is not strictly necessary for a lid – a slowing of the lapse rate is all that is required for a previously buoyant air parcel to encounter some *convective inhibition* (CIN).

The origin of lids on the climatological has not been studied in any great depth but, given their characteristics and results from individual case studies, it is likely that the majority are derived from *residual layers* (i.e. remnants of the previous day's boundary layer) or *dry layers* that have descended from the upper-troposphere/lower-stratosphere.

2 A DEFINITION OF ATMOSPHERIC LIDS

Carlson et al. (1980) developed a Lid Strength Index (LSI) in the context of severe storm initiation in the Midwestern United States. The LSI compares buoyancy of an atmospheric profile with the lid effect thus:

$$LSI = \left(\bar{\theta}_w - \tilde{\theta}_{sw}\right) - \left(\theta_{swl} - \bar{\theta}_w\right) \tag{1}$$

Where, in the presence of a lid, $\bar{\theta}_w$ equals the mean wet-bulb potential temperature in the lowest 50 hPa, θ_{swl} equals the maximum saturation wet-bulb potential temperature and $\tilde{\theta}_{sw}$ equals the mean saturation wet-bulb potential temperature between θ_{swl} and 500 hPa. Therefore, a positive LSI means there is potential for convection without further forcing (e.g. lifting, heating) and a negative LSI implies that convection would be inhibited. However, the LSI give little indication of the thickness of the lid, whether there are multiple lids or what the relative rates of change of the lid strength and the surface layer temperature are.

3 PREVIOUS STUDIES OF ATMOSPHERIC LIDS

A number of cases from a recent UK field campaign – the Convective Storm Initiation Project (CSIP) – highlighted the importance of lids in the development of convective storms. In a summary of that project, Browning et al. (2007) discussed the role of lids in general whilst Morcrette et al. (2007), Russell et al. (2008, 2009) and Bennett et al. (2008) examined their role in individual cases in much greater detail. In particular, Russell et al. (2008) were concerned with the origin of the lid that they examined. In their case the lid had descended from the upper-troposphere but it is unclear whether the main source of lids is from descent, residual layers or differential advection, as speculated by Graziano and Carlson (1987).

Bennet et al. (2008) examined a case from the UK where multiple stable layers influenced the development of convection that led to some small showers. In particular, they consider how best to interpret radiosonde data with respect to understanding how convection develops. It would be interesting to extend their study and try to determine where these multiple stable layers came from.

Graziano and Carlson (1987) conducted an analysis of lid strength versus severe storm activity over a six month period in 1982 for the central two-thirds of the USA. Their study, representing one of the only systematic analyses of the role of lids in the initiation of convection, revealed that in order to understand the onset of severe convection both lid strength and buoyancy must be considered. For example, they found an LSI "cut-off value" above which severe convection was rarely observed. However, whilst the probability of deep convection decreases with increasing LSI, they found that when considering a given value of buoyancy the deep convection probability increased with increasing LSI.

4 SUMMARY

This extended abstract represents a short overview of the scientific literature on the subject of atmospheric lids. A suitable way to summarise this paper, therefore, is the following brief list of research questions that this review has thrown up. Here is this list:

- How important are lids in determining the strength of convective storms?
- How important are lids in determining the location of convective storms?
- How well do numerical weather prediction (NWP) models represent lids?
- Has the climatological occurrence of lids changed in recent time?
- Where do lids come from?
- Are the answers to the above questions significantly different in different geographical areas?

The data collected and the NWP models run during the COPS campaign, as summarised by Wulfmeyer et al. (2008), provide an ideal dataset to answer some of these questions.

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