INITIATION OF PRECIPITATING CONVECTION BASED ON DATA ANALYSIS

Khodayar, S., Kalthoff, N.

Institut für Meteorologie und Klimaforschung, Universität Karlsruhe/Forschungszentrum Karlsruhe, Postfach 3640, 76021 Karlsruhe, Germany, Samiro.Khodayar@imk.fzk.de

(May 1, 2007)

I. INTRODUCTION

Thunderstorms, and precipitation associated with deep convection in general, are an important ingredient in many high-impact events such as flash floods. Such events are highly localized but predicting where such storms will break out is one of the major challenges facing meteorologists.

Many events are known where immense flash flooding occurred and homes were destroyed. If in those cases people had been given warning then they could have been prepared and protected some of their properties. Events such as this provide motivation for the Convective Storm Initiation Project (CSIP). The goal of CSIP is to increase the understanding of the initiation of convective storms. The CSIP field campaigns were performed during the summers of 2004 and 2005 on the south region of the UK. This area is characterized by an intermediate level of orography together with nearby coastlines. Furthermore, the maritime nature of the British climate and the absence of major mountains mean that the convective instability and capping inversions are often quite weak on convective occasions.

This work is concerned primarily with research aimed at understanding the mechanisms responsible for the initiation of precipitating convection based on data analysis.

During CSIP, most of the cases encountered were due to convection initiating in the boundary layer (Browning et al., 2006a). Boundary forcing has long been known to be a cause of thunderstorm initiation. The great number of instruments used, as radiosondes, mesonet, lidar, sodar, wind profilers, satellite and radar imagery and two instrumented aircrafts among others, and the highly dense net of measurements available in the investigation area allow us to analyze in detail the structure of the boundary layer before, during and after convective outbreaks.

A characteristic feature of the atmosphere in situations leading to the outbreak of deep convection is the stable layer phenomenon called lid. A lid is a lower tropospheric inversion, which allows heat and moisture, two of the basic ingredients for thunderstorms to form, to accumulate in the boundary layer during the day and serve as the fuel for future thunderstorms. Many factors have to be studied to define properly the lid structure to represent them adequately; the variation of the lid in space and time, the existence of multiple lids …etc. Therefore, the analysis of mechanisms that cause moist low-level air to break through the lid in one place rather than another, and the location of small-scale moisture or temperature anomalies or "hot spots", should give us some hints about the timing and location of initiation of convective storms.

II. PRESENTATION OF RESEARCH

A combination of radiosondes, aircraft observations, Dornier-128 and Cessna, automatic weather stations (AWSs), SYNOP stations and Global Positioning System data (GPS) are used to analyze the CSIP IOP5, 29 June 2005. On this day, the mesoscale model forecast showed widespread showers in the CSIP area by 1200 UTC. In the event, the showers became widespread slightly later than this within the CSIP area but they did become intense enough to form a band of heavy precipitation extending east west across Britain. Because of this heavy rain, some flash flooding occurred in Oxfordshire (Fig.1).

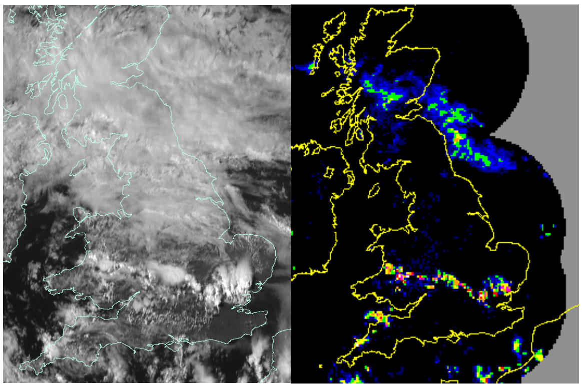

Fig. 1: Meteosat Second generation (MSG) satellite image (left) and radar rain-rates (right) at 15:00 UTC on 29 June 2005.

The line of storms approximately 100 km northeast of Chilbolton developed from showers that initiated near Chilbolton, which are the subject of this study. At 12:00 UTC a cumulonimbus appears approximately 20 km northeast of Chilbolton. By 13:00 UTC there were two significant showers, which had grown in size and have been advected northwards.

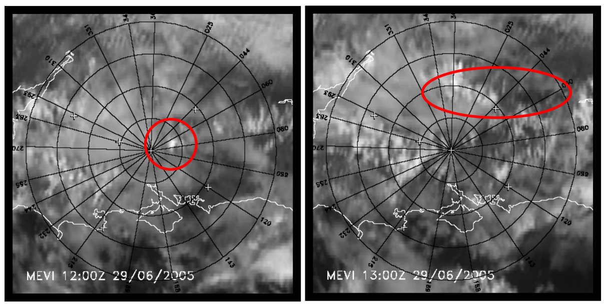

Fig. 2: Meteosat Second Generation image (MSG) at 12:00 UTC (left) and 13:00 UTC (right). Range rings are centred on the Chilbolton radar and shown at 25 km intervals. Positions of the radiosonde sites are indicated by white crosses (west to east are Bath, Larkhill, Chilbolton and Reading).

III. RESULTS AND CONCLUSIONS

Our main goal in the present work is to estimate the location of the primary initiated convective cell by means of different mesoscale data sets. We analyze which set of meteorological parameters show the main variability's in the PBL and which is the impact of their variations on convection.

For us it is essential to understand what controls boundary-layer development and variability. With this purpose we make use of radiosondes, aircraft observations, automatic weather stations (AWSs), SYNOP stations and GPS data, the latter giving us column Integrated Water Vapor (IWV). Our aim is to try to find the location of small-scale moisture or temperature anomalies or "hot spots" which could give us some hint about the timing and location of initiation of convective storms. It has been demonstrated that in some situations boundary layer circulations can by themselves lead to convective initiation (Weckwerth, 1999). Therefore, we are interested in the analysis of the surface or boundary layer inhomogeneities that lead to the triggering of mesoscale atmospheric circulations responsible of the initiation of convection. It has been also demonstrated that these temperature or moisture inhomogeneities must be in the order of 10 km (Schaedler, 1989). Making use of the temperature and moisture obtained from the above-mentioned meteorological tools, we create linearly spatial interpolated fields (0.1ºx0.1º). The borders of these interpolated fields rely on the boundary position of the radiosonde stations at the CSIP investigation area. Six radiosonde stations are located in the CSIP area. Radiosoundes were launched every one or two hours from Bath, Swanage, Larkhill, Chilbolton, Reading and Preston Farm. Each separated from its nearest neighbour by between 25 and 50 km. As expected, the small-scale horizontal variations in the boundary layer cannot be resolved by the network of radiosondes. Therefore, we increase our resolution by means of surface and mid-level boundary layer measurements above mentioned. The combination of aircraft data and radiosonde data at the same altitude, 500 m MSL, show that the spatial distribution of the temperature is more homogeneous than the moisture distribution. In addition, the moisture distribution shows boundary layer inhomogeneities in the order of 20 km, sufficient to generate by its one mesoscale circulations. It was expected that the AWSs and the SYNOP stations would show us a connection between the small scale temperatures or moisture variation and the primary initiated convective cell observed in Fig.2. However, no link between these measurements and the convective cell observed in the CSIP area could be found. GPS data offer us the possibility to study the moisture with a high-resolution distribution. Although GPS data give us column integrated water vapour data we assume that the larger amount of water vapour can be found in the boundary layer. In order to relate the IWV data with water vapour mixing ratio in the PBL, a linear regression is applied between IWV data at the radiosonde station location and the mixing ratio measured at a characteristic level at the boundary layer at the same locations. The water vapour mixing ratio variation denotes a clear relationship with the initiation of convection in the CSIP area. The pink stars showing the location of the primary initiated cell observed in Fig.2 coincides with the area where moisture starts increasing dramatically (Fig.3).

Early in the convective boundary layer, convection was constrained by a stable lid near 1 km. When convection finally broke through the lower lid it ascended to a second lid at roughly 600 hPa leading to some very light showers. Eventually the convection penetrated the second lid and rose toward the tropopause level to produce intense thunderstorms, some of which produced flash flooding in Oxfordshire after 1500 UTC. A second part of this work focuses on the analysis of different stability parameters that could help us in the estimation of the location of the primary initiated cell.

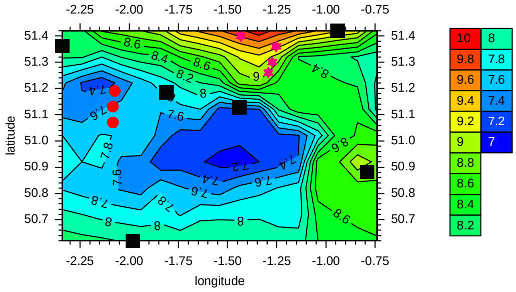

Fig. 3: Water vapour mixing ratio in g/kg obtained from IWV measurements. Black squares show the location of the six radiosonde stations in the investigation area named as follows, from west to east are Bath, Swanage, Larkhill, Chilbolton, Reading and Preston Farm. The pink stars and red circles show the initiated convective cells at this time, 12:00 UTC, calculated by superimposition of radar and satellite data (thanks to Cyril Mocrette, Met Office).

With this purpose, five convective indices (CI) are analyzed; Convective Available Potential Energy (CAPE), Convective inhibition (CIN), Lifted Index (LI), Lid Strength Index (LSI) and Bulk Richardson Number (BRN). We think that a convective index alone is not sufficient in ascertaining the probability of having a storm; we look for a combination of convective indices that could give us a good estimation.

Our initial hypothesis is that regions where deep convection is predicted should be limited to regions of negative lifted index and outside the 2.0 lid contour. This hypothesis is confirmed for this case study, deep convection develops in the area predicted.

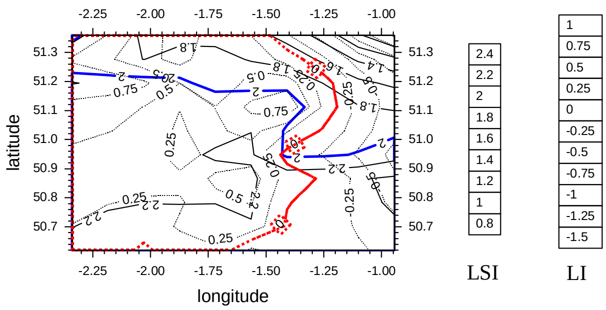

Fig 3: Spatial distribution of Lid Strength Index (LSI) and Lifted Index (LI) both in degrees Celsius, in the area of investigation. The 0.0 line corresponds to the LI which separates the negative and positive LI areas. The 2.0 degrees line corresponds to the LSI.

The modification of the initially interpolated profiles with the mid-boundary layer moisture shows again a clear relation with the primary initiated convective cell.

IV. REFERENCES

- Browning, K., Blyth, A., Clark, P., Cosmeier, U., Morcrette, C., et al., 2006a: The Convective Storm Initiation Project, *Bull. Am. Met. Soc.*, Submitted
- Lanicci, J. M., Warner, T. T., 1991:2006: A synoptic climatology of the elevated mixed-layer inversion over the southern Great Plains in spring. Part I: structure, dynamics, and seasonal evolution. *Wea. Forecasting*, 6, 181-197.
- Schaedler, G., 1989: Triggering of atmospheric circulations by moisture inhomogeneities on the Earth's surface. *Boundary-Layer Meteorology*, 51 1-29.
- Weckwerth T. M., 1999: The effect of Small-Scale Moisture Variability on Thunderstorm Initiation. *Mon. Weather Rev.*,128, 4017-4030