A CASE STUDY OF COLD AIR POOL EVOLUTION IN HILLY TERRAIN USING FIELD MEASUREMENTS FROM COLPEX

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Introduction

A case study investigation of cold air pool (CAP) evolution in hilly terrain is conducted using field measurements made during IOP 16 of the Cold Air Pool Experiment (Price et al., 2010; see map right).

During Episode 1 of COLPEX a strong CAP was observed and a summary of the night is given by Price et al. (2010). At sunset the CAP evolved uninterrupted; the wave activity in Episode 1 may highlight the phenomena, which are defined using LIDAR measurements of vertical velocity.

Episode 1 – Wave activity

Prior to Episode 1 there was sustained uninterrupted growth of the CAP; however, during Episode 2 the CAP is disturbed and highlighted by a change in behaviour of the EUR (Fig.3). Drainage flows also appear disturbed after Episode 1 (Fig.4)

Episode 1 is characterised by between 6 and 8 intermittent increases in the LIDAR vertical velocity profile (referencing to the LIDAR measurements, centre figure) that occur in the region at and above the hill tops near Duffryn (200 to 400m AGL).

At ~22:30 a wave-like feature is seen at the top of the LIDAR profile and at ~23:00 UTC, a period of sustained downward vertical velocities are seen that extends throughout the LIDAR profile depth.

Results of radiosonde ascent speed profiles (Fig.4) suggest evidence of gravity wave activity.

• Bulk Richardson number (Rb, Fig.5) suggest the region between hill tops and the Burfield valley are in transition between laminar and turbulent flow, despite ambient winds being relatively light (Springhill, Fig.5). Springhill to Duffryn (50m) is more stable (not shown).

Episode 2 – Erosion of residual layer

• Episode 2 is characterised by a region of increased vertical velocities, that decays with time down to hill top region (centre figure).

The region of increased vertical velocities is first seen in the LIDAR around 01:00 UTC at ~80m AGL. By ~01:50 it descends below the surrounding hill tops and extends throughout the profile depth.

Over the same time period the ambient wind at Springhill increases sharply above a 1 h period, accelerating from around 2 m/s to around 4 m/s (Fig.5).

• After Episode 2 ambient winds remain relatively high at around 4 m/s, with fluctuations between 3 and 5 m/s.

• The region between Springhill and Burfield is also changing from a stable laminar regime to a more turbulent/laminar regime (Fig.5).

Discussion and conclusions

• A case study using a unique set of field investigations from COLPEX (Price et al., 2010), highlights a number of meteorological phenomena that occur during CAP evolution in hilly terrain.

• During Episode 3 the LIDAR vertical velocities are distinctly different compared to any time previous, appearing characteristically more turbulent. This is further emphasised by the Rb profiles, which show the region between Burfield and Springhill to be persistently less stable than previous.

• Radiosonde profiles show the formation of a nocturnal jet during the night (Fig.6:05:35 profile).

• Associated with this jet is a strong wind speed gradient and a veering of the wind direction with height ~100 m AGL.

• CAP breakup occurs some 3 hours after sunrise between 10:00 and 10:30 UTC. Just prior to CAP breakup a region of increased vertical velocities descends with time (similarities to Episode 2).

References:


Overview of IOP 16

• IOP 16 was one of the strongest CAPs observed during COLPEX (Fig.1), with temperature differences between the hill top and valley floor peaking at ~13 °C around sunrise, following a rapid development of the CAP (Fig.2).

• Skies remained clear during the night, and no fog formations were recorded (see Fig 3 E). Temperatures in hill top regions remained at or above freezing during the night, while frost formed in the valleys.

• Following sunset the CAP evolved uninterrupted, however, ~4 h after sunset (~10:30 UTC) the Environmental Lapse Rate (ELR) shows interruptions in the CAP evolution, which continue intermittently until CAP break up in the morning.

Episode 3 – NLLJ and CAP break up

During Episode 3 the LIDAR vertical velocities are distinctly different compared to any time previous, appearing characteristically more turbulent. This is further emphasised by the Rb profiles, which show the region between Burfield and Springhill to be persistently less stable than previous.

Radiosonde profiles show the formation of a nocturnal jet during the night (Fig:05:35 profile).

Associated with this jet is a strong wind speed gradient and a veering of the wind direction with height ~100 m AGL.

CAP breakup occurs some 3 hours after sunrise between 10:00 and 10:30 UTC. Just prior to CAP breakup a region of increased vertical velocities descends with time (similarities to Episode 2).

Fig.1. COLPEX climatology of Hill Valley CAP strength.

Fig.2. Analysis at 00:00 UTC 3 March 2010

Fig.3. Time-series of valley EUR and RH: Top: top (Springhill, 30m AGL), Bottom (Springhill, 30m AGL) and Burfield valley (Burfield valley are in transition between laminar and turbulent flow, ~200 to 400m AGL).

Fig.4. Radiosonde ascent speed profiles launched from the valley floor site near Duffryn (200 to 400m AGL).

Fig.5. radiosonde profiles launched from valley floor site Duffryn, showing wind speed and direction with height above ground level.

Fig.6. Radiosonde profiles from valley floor site Duffryn, showing wind speed and direction with height above ground level.

Fig.7. Typical nocturnal boundary layer from COMET, adapted from Whiteman (2000).

Fig.8. Generalised depiction of CAP evolution and associated phenomena during IOP 16 of COLPEX.

Fig.9. Potential temperature (°C) and mixing ratio (%).

Fig.10. Relative humidity (%) and Potential temperature (°C).

Fig.11. Potential temperature (°C) and Mixing ratio (%).

Fig.12. Potential temperature (°C) and Mixing ratio (%).