Sensitivity of cold air pool evolution in hilly terrain regions

Bradley Jemmett-Smith[1], Andrew Ross[1], Peter Sheridan[2], John Hughes[1]

21st Symposium on Boundary Layers and Turbulence
Leeds, UK

9 June 2014

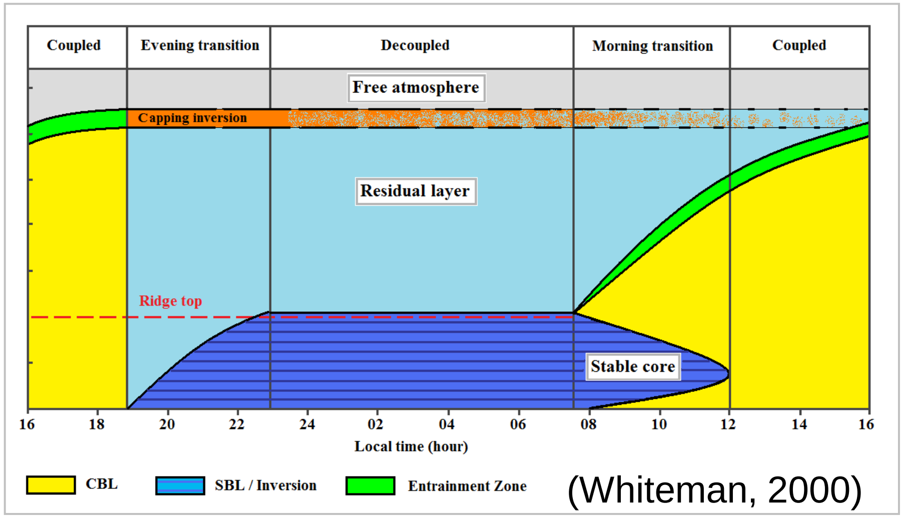
[1]Institute of Climate and Atmospheric Science, University of Leeds, UK
[2]Met Office, Exeter, UK

Clun Valley, Shropshire, UK

Cold air-pools (CAPs) in complex terrain

- Develop around sunset, forming in dips, hollows, valleys or basins etc.
- Cold air pools (drainage flows/katabatic winds) and/or cools in-situ.
- Break-up following sunrise as CBL establishes.
- Ideal conditions; low wind speeds, no cloud cover, stable atmospheres.

Nocturnal Boundary Layer



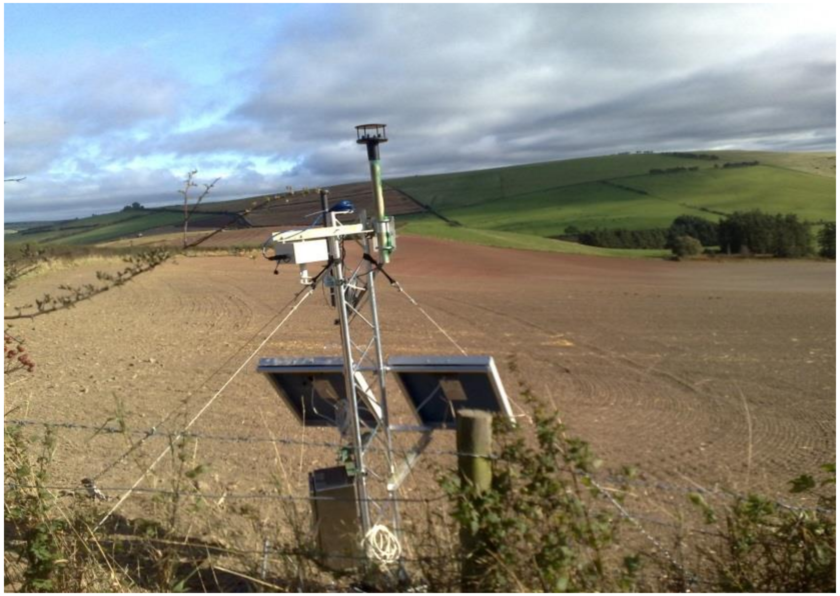
(Whiteman, 2000)

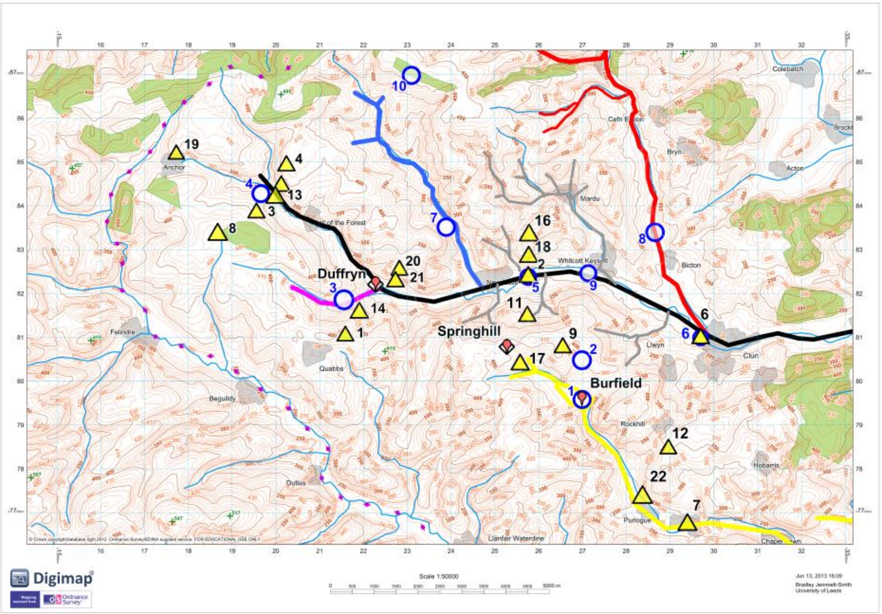
Why?

- Hazardous driving conditions; frost, fog, persistence of lying snow.
- Health risks; pollution episodes.
- Representation in Numerical Weather Prediction models; unresolved scales, SBL parameterizations, surface energy balance.
- Improve understanding of SBL processes; better representation of minimum temperature, fog, frost etc.
- Recent capabilities allow high resolution modelling of scales <1km.
- Application of downscaling techniques, e.g., for improved road temperature forecasts.

COLd air Pooling EXperiment (COLPEX)
Unique data set of SBL observations

- Comprehensive field campaign, June 2009 to April 2010.
- University of Leeds, Met Office, NCAS.
- Satellite weather stations (HOBOS, AWS), wind, temperature and pressure.
- Large flux towers; components of the energy budget – see Price et al, (2011).
- Valley depths ~200m, widths typically 1km.

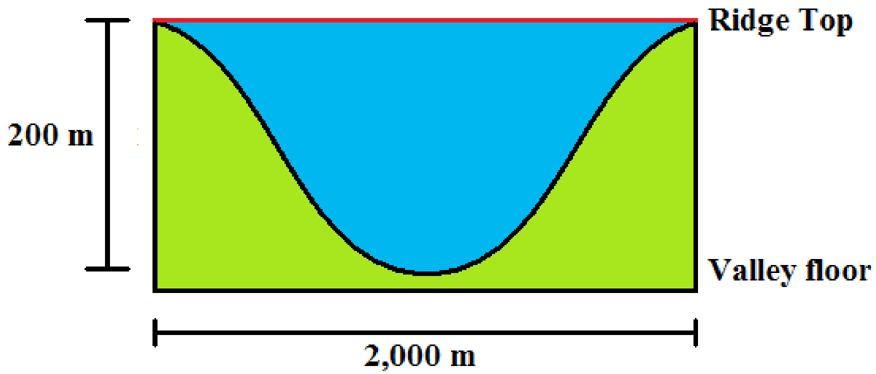




How often do they occur?

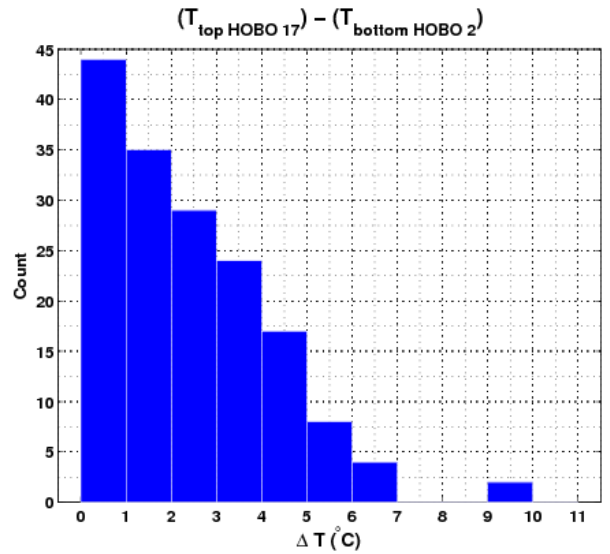
9–month climatology

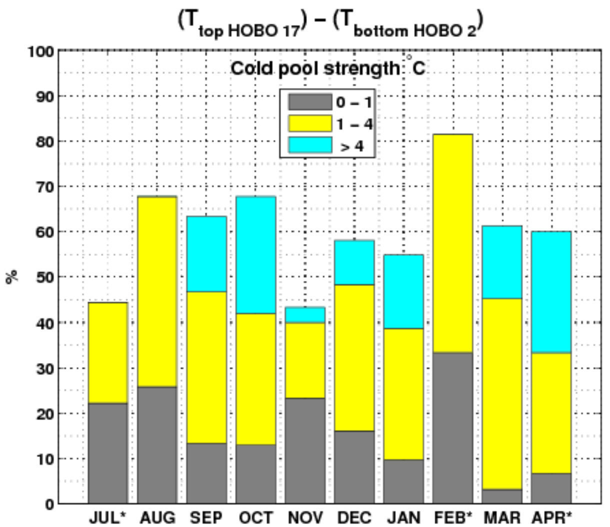
• Nights with temperature inversions greater than 4°C occur 23% of the time.



• Strong CAPs frequent during October and April – periods of prolonged high pressure.

• Strongest CAP observed 7-8th January, exceeding 9.9°C: ~5°C/100m. Tmin = -18.2°C.

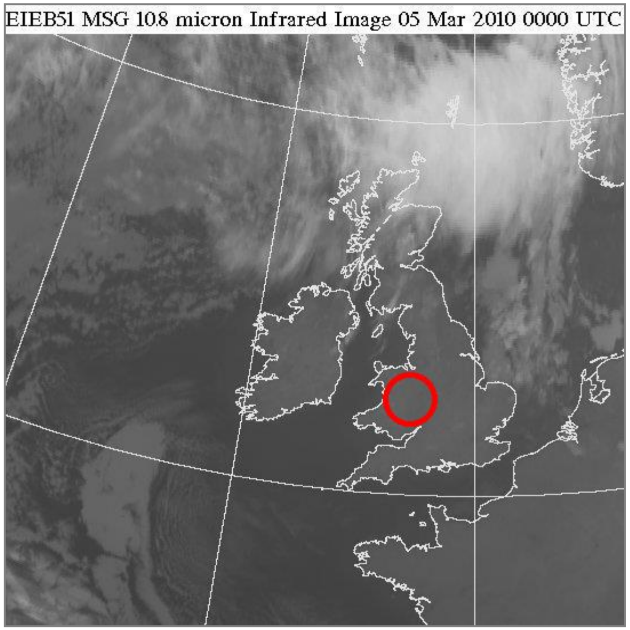




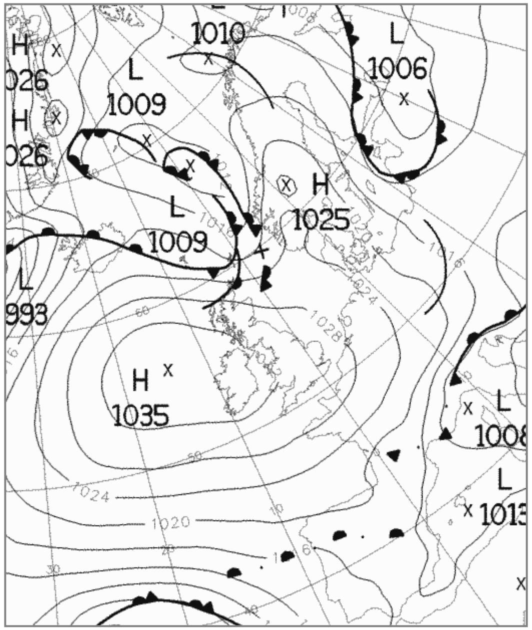
"Ideal" case study – Synoptic conditions

IOP 16
4-5 March 2010

- High pressure
- Low wind speeds
- Clear skies



IR sat image 00:00 UTC
5 March 2010

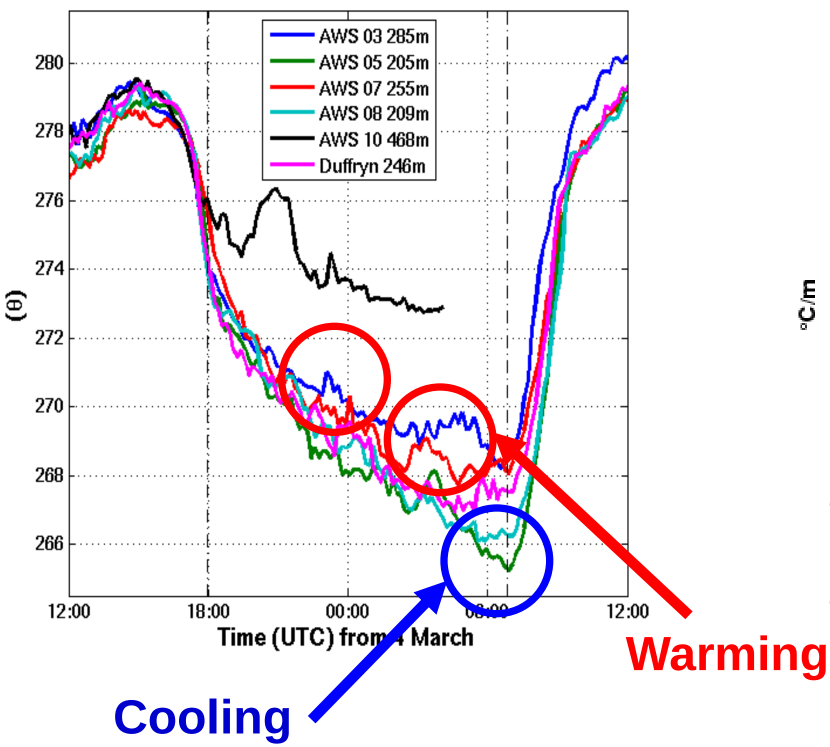


Analysis 00:00 UTC
5 March 2010

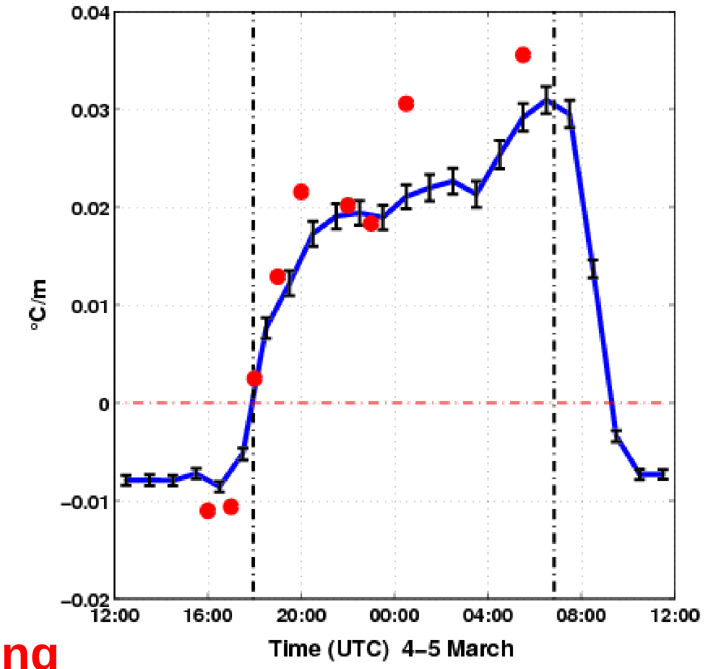
Theta and ELR evolution

4–5 March 2010

Potential temp

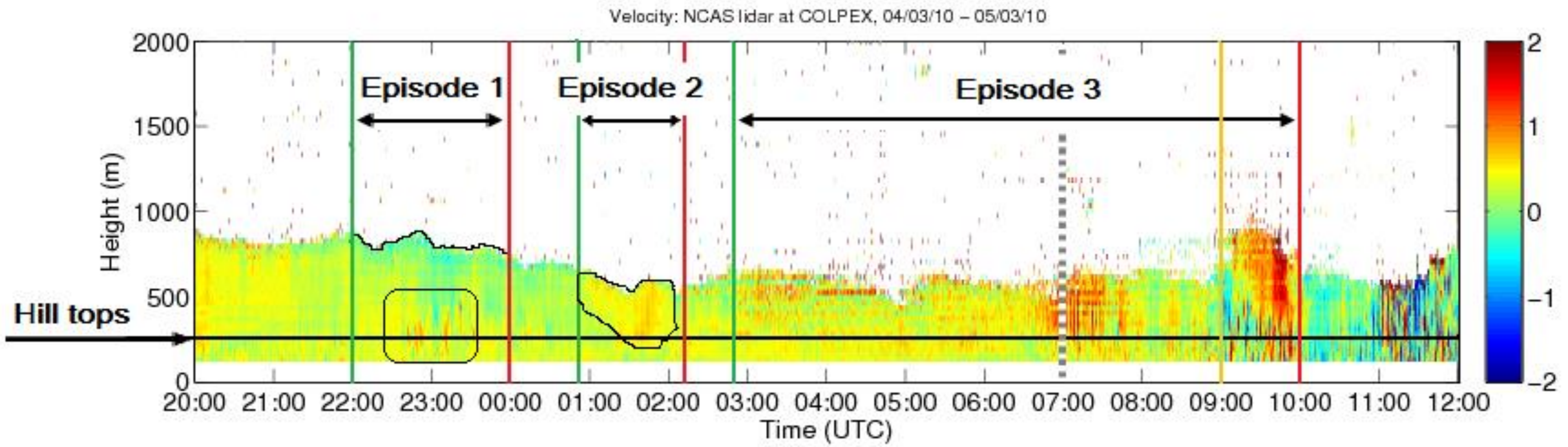


Env. Lapse rate



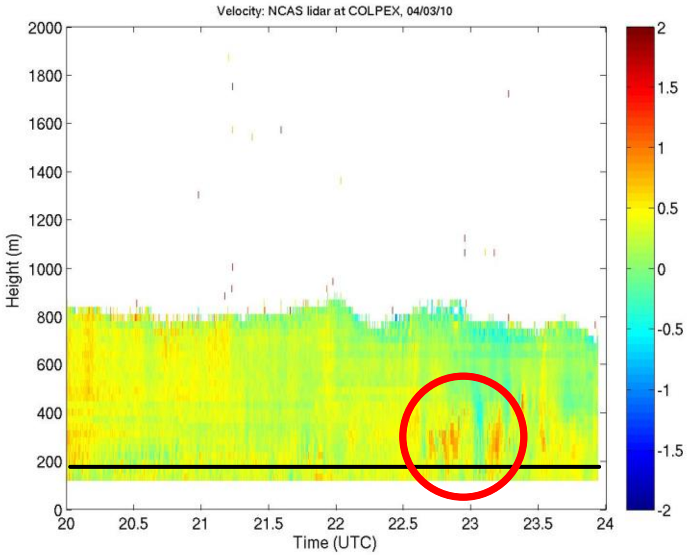
Episodes of evolution disruption

LIDAR vertical velocity
4-5 March 2010

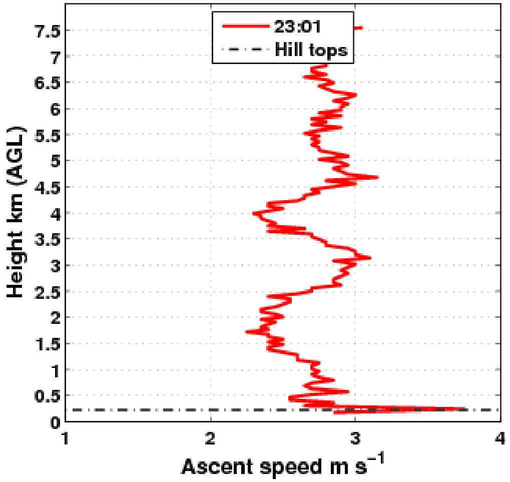


Episode 1 – Gravity wave activity?

LIDAR
Vertical velocities

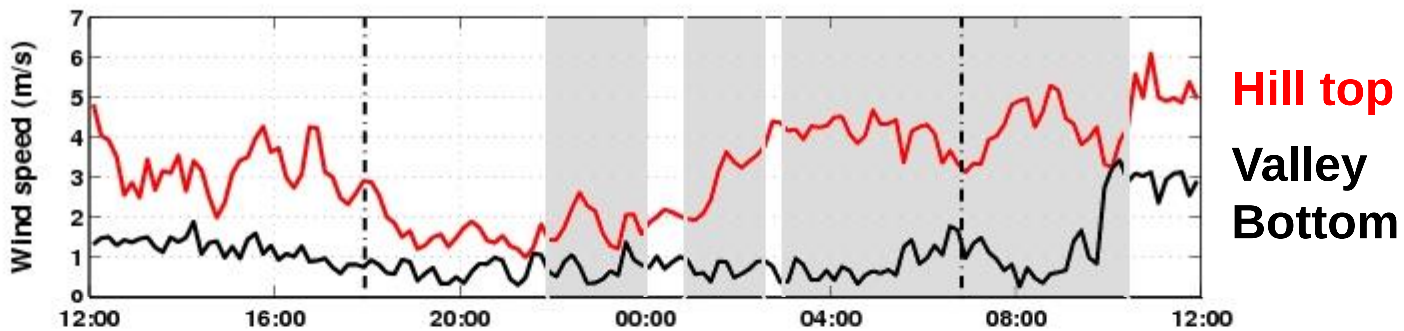


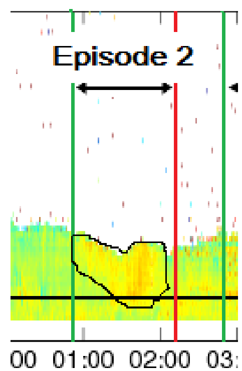
Radiosonde
ascent rate



Episode 2 – Momentum mixed down?

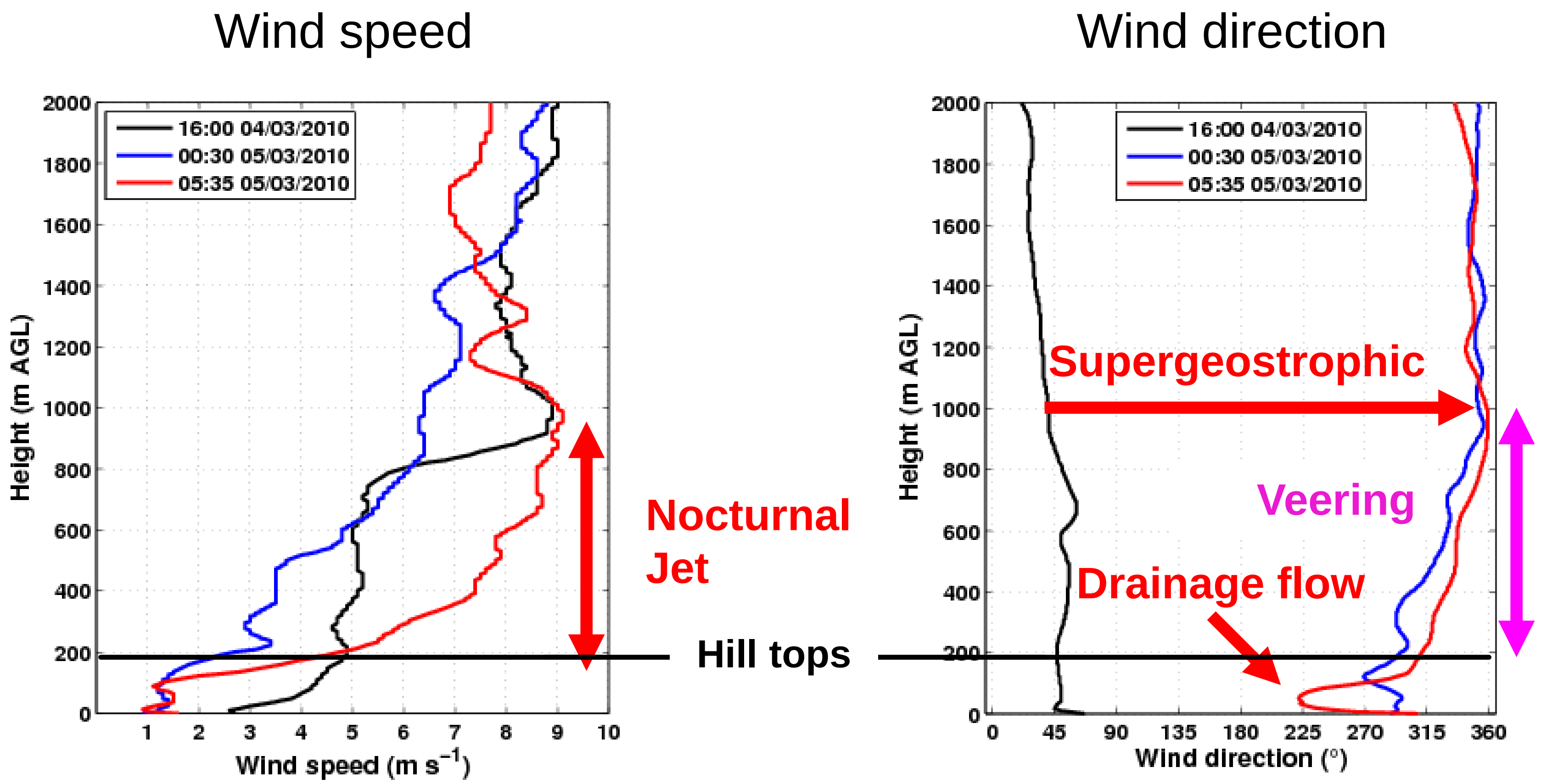
Wind speed t-series





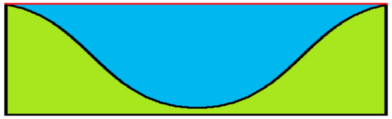
Episode 3 – Nocturnal Low Level Jet (NLLJ)

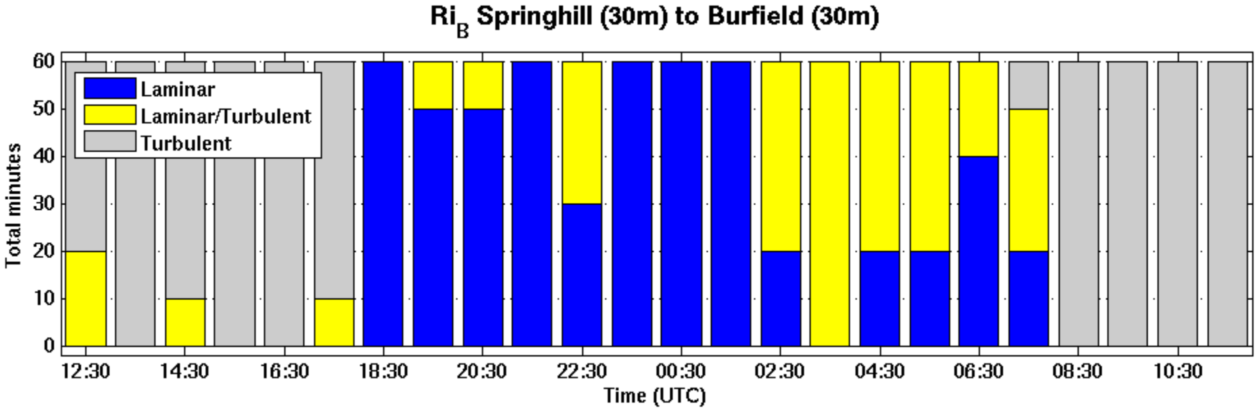
Duffryn sondes



Evolution of valley stability

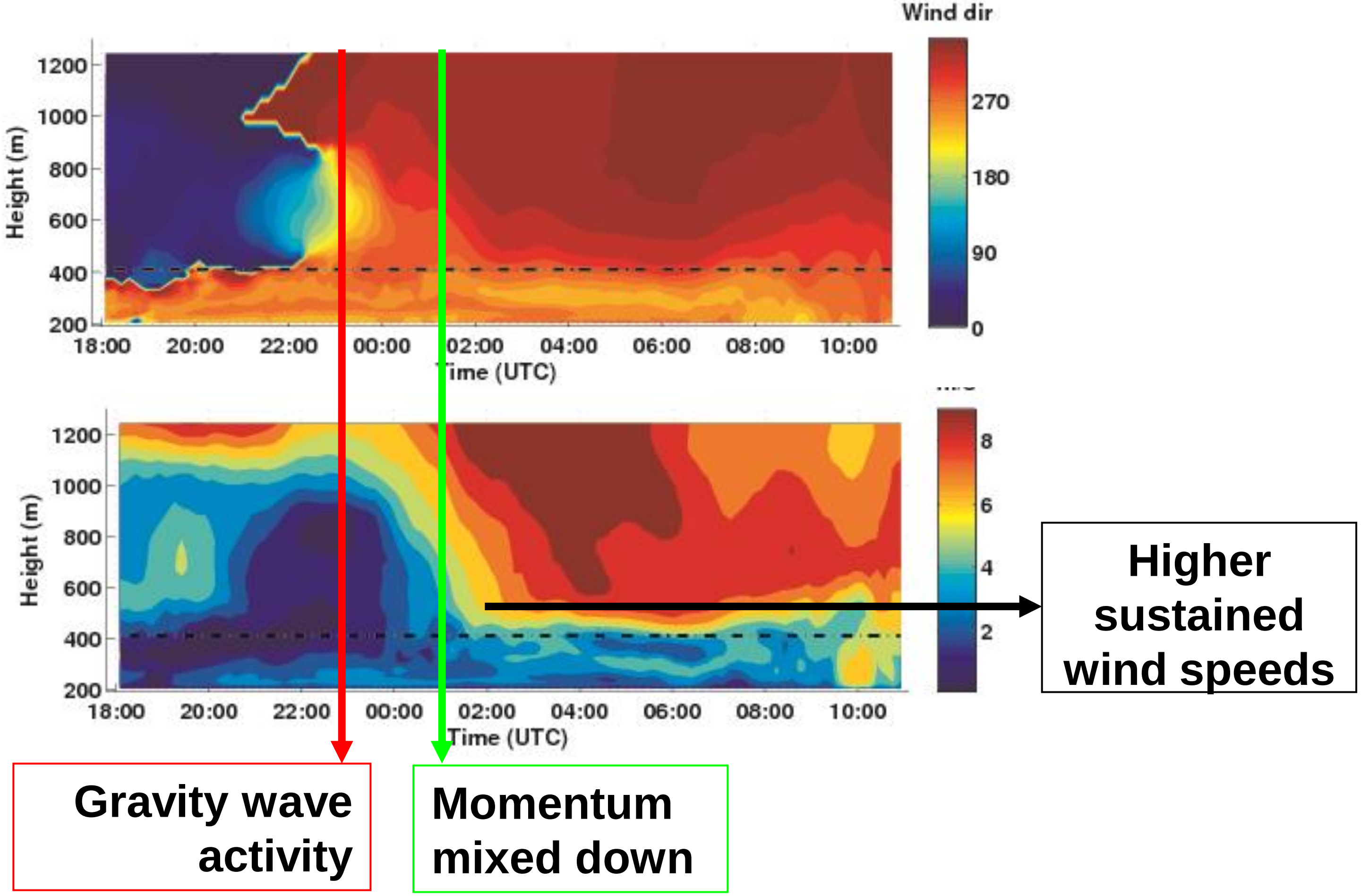
Bulk Richardson number





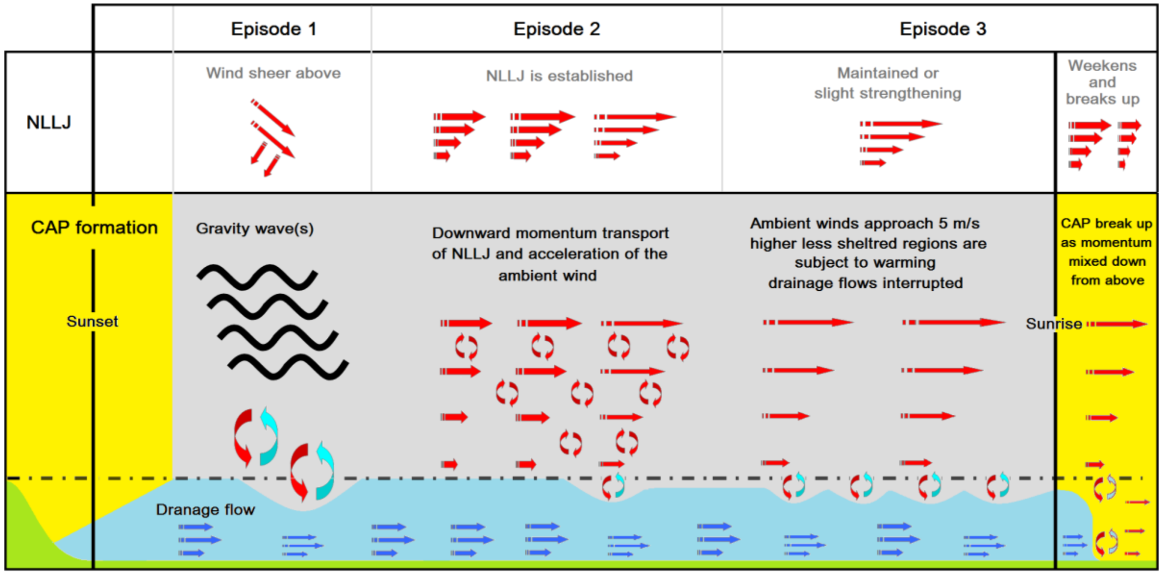
Model representation

Wind speed and direction vertical profile, from valley bottom, Duffryn



Summary

- CAPs observed frequently throughout COLPEX.
- Relatively small changes in synoptic wind affect CAP evolution during ‘’ideal’’ case study.
- CAP evolution was disturbed, and characterised by three episodes:
  - Gravity wave activity; possibly caused by wind speed/directional shear.
  - Downward momentum transport of the developing NLLJ, accelerating hill top wind speeds.
  - Established NLLJ, with hill top winds of 4—5 m/s.
- The developing NLLJ appears to be the overriding factor.



Thank you for listening.

Any questions?

COLPEX Publications

Publications

Vosper, S., Hughes, J., Lock, A., Sheridan, P., Ross, A., **Jemmett-Smith, B**., and Brown, A. 2013: Cold pool formation in a narrow valley. Quarterly Journal of the Royal Meteorological Society. doi: 10.1002/qj.2160

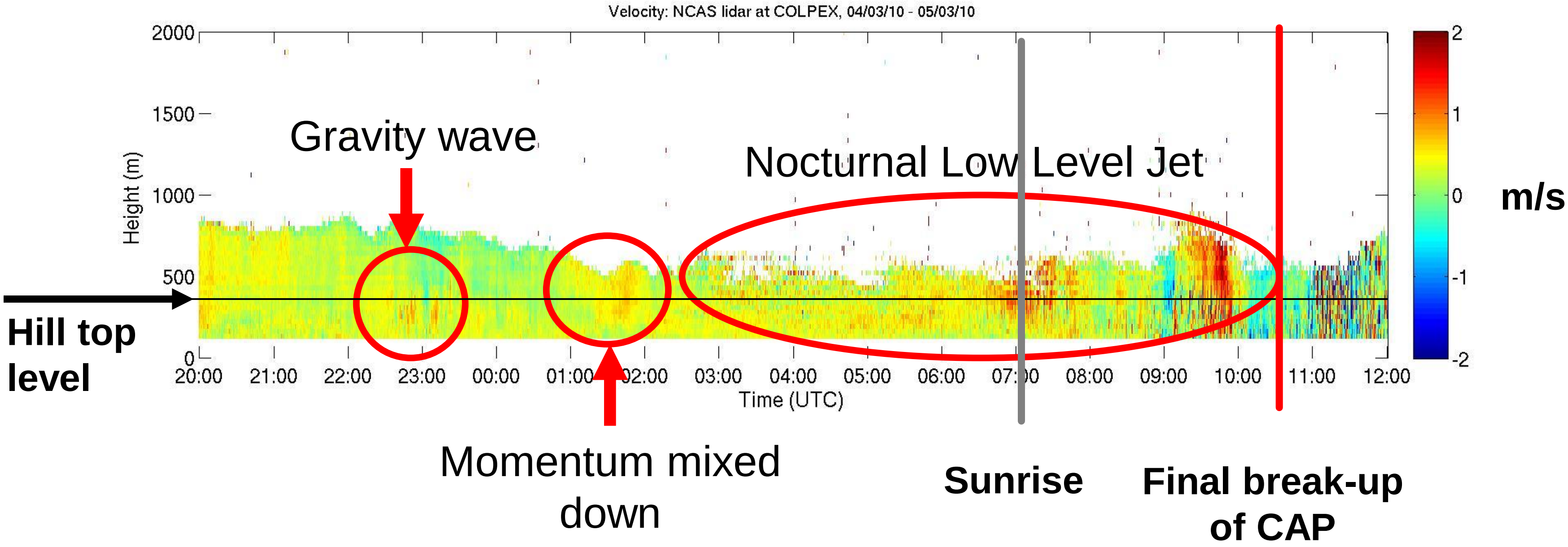
Price J. D. , Vosper S., Brown A., Ross A., Clark P., Davies F., Horlacher V., Claxton B., McGregor J. R., Hoare J. S., **Jemmett-Smith B**., and Sheridan P. 2011: COLPEX: Field and Numerical Studies over a Region of Small Hills. Bull. Amer. Meteor. Soc., 92, 1636–1650. doi: http://dx.doi.org/10.1175/2011BAMS3032.1

Sheridan, P. F., Vosper, S. B., and Brown, A. R. 2013. Characteristics of cold pools observed in narrow valleys and dependence on external conditions. Quarterly Journal of the Royal Meteorological Society.

Price J. D. , Vosper S., Brown A., Ross A., Clark P., Davies F., Horlacher V., Claxton B., McGregor J. R., Hoare J. S., **Jemmett-Smith B**., and Sheridan P. 2011: COLPEX: Field and Numerical Studies over a Region of Small Hills. Bull. Amer. Meteor. Soc., 92, 1636?1650. doi: http://dx.doi.org/10.1175/2011BAMS3032.1

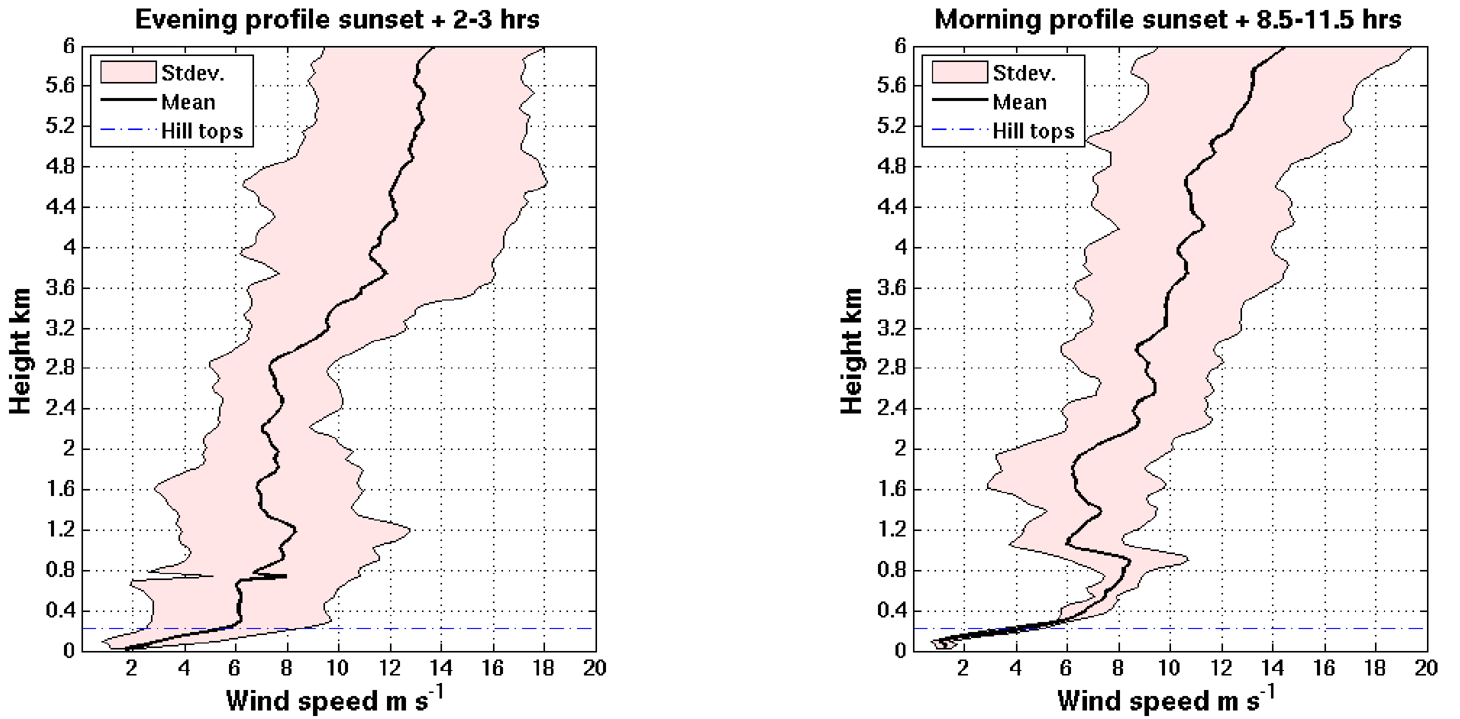
NLLJ the overriding factor?

LIDAR vertical velocity
4-5 March 2010

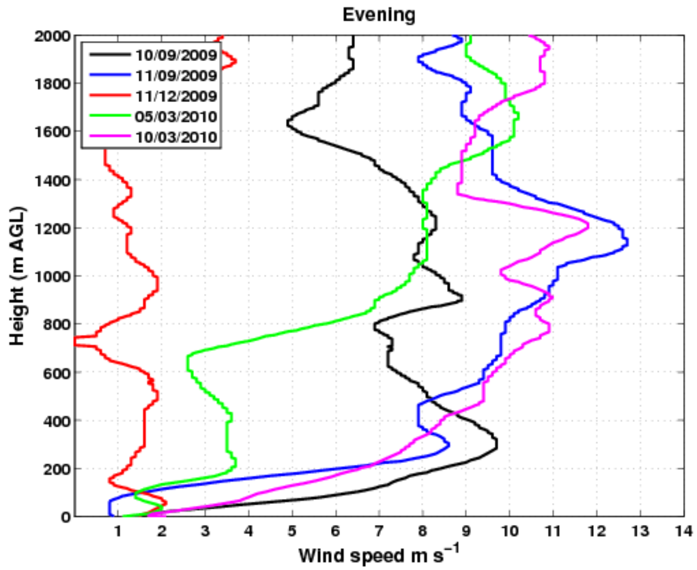


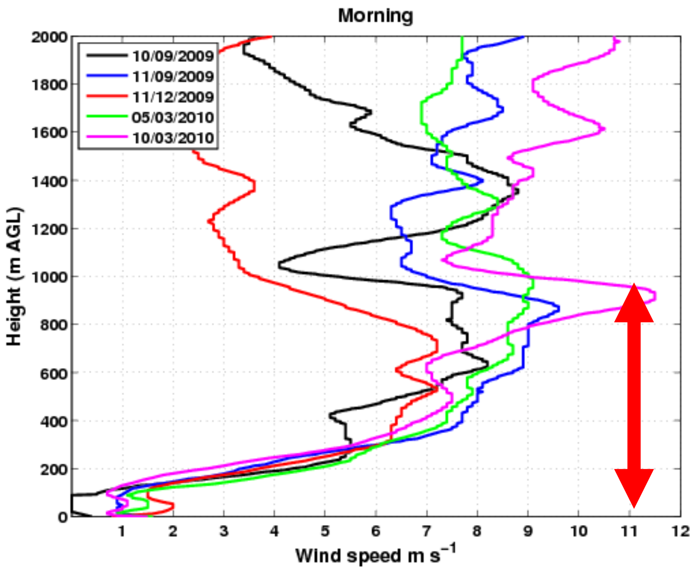
Recurrence of the NLLJ

Mean of 5 profiles on separate CAP nights



Recurrence of the NLLJ?





Consistent

Conditions ideal for CAPs to form

Results from 9–month climatology: July 2009 – April 2010

Strong CAPs in the Clun Valley…….

Preferentially form when:

- Ambient wind <7 m/s
- Msl pressure >1008 hPa
- Wind dir from N or NW
- Dry, clear (Flw < 0.91)

Ideal conditions:

- Ambient wind <3 m/s
- Msl pressure >1029 hPa
- Wind dir from N
- Low values of Flw, i.e., 0.80.