Analysis of Convection Initiation Processes in Complex Terrain with the Synergy of COPS Remote Sensing Data

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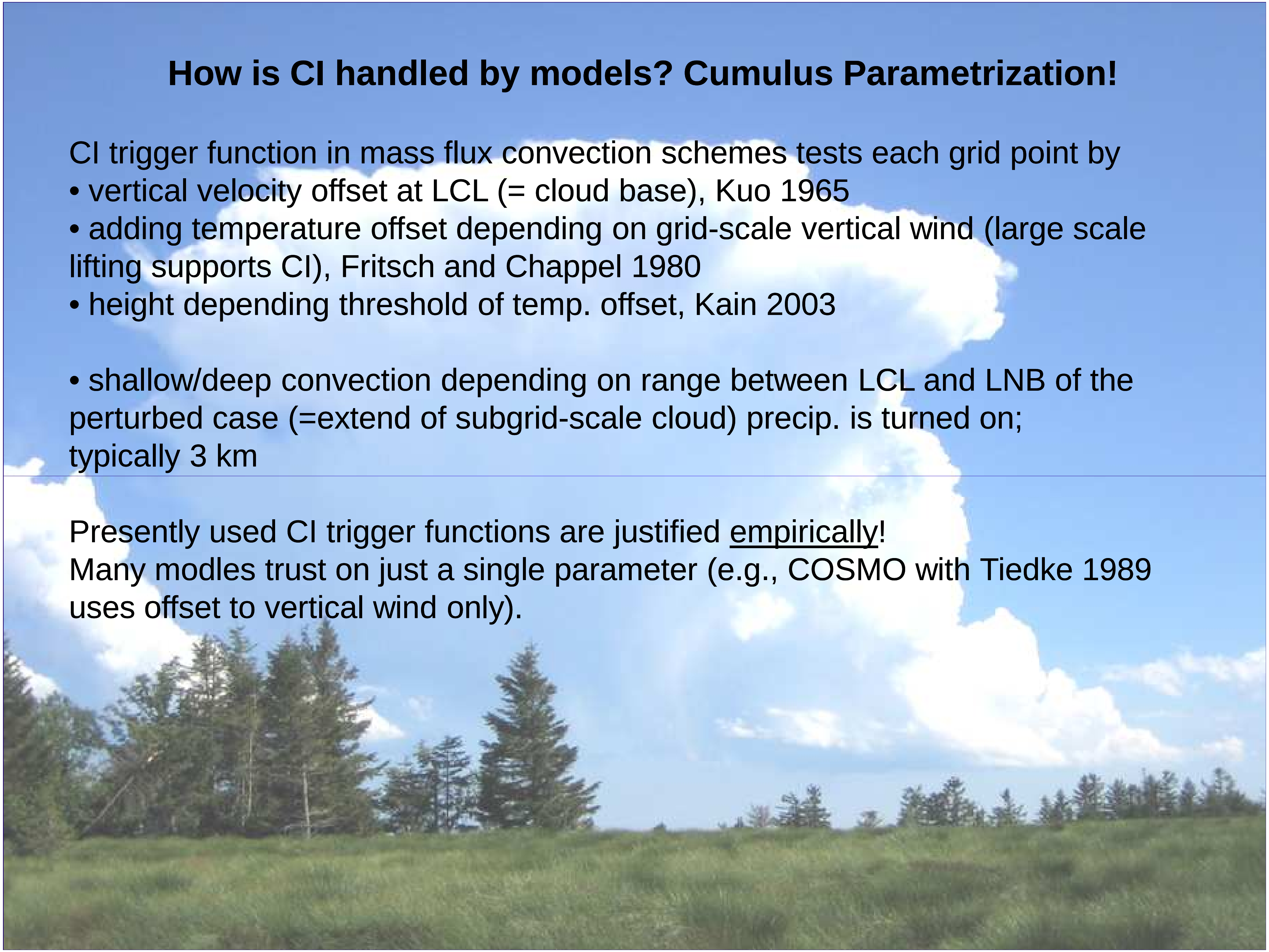
Initiation of (Deep) Convection (CI)

Analyses ahead of COPS indicated that CI in complex terrain is mainly determined by

- the convergence and updrafts created by forced lifting on the windward side and thermally-forced anabatic flow,
- the wind shear profile in the region of the ridges,
- ·variations in the depth of the convective boundary layer as well as in moisture, convective inhibition (CIN), and convective available potential energy (CAPE) across the mountain ridges,
- ·the presence of gravity waves impinging on the ridges,
- ·aerosol loading in the pre-convective environment influencing the diurnal cycle of boundary variables.



How is CI handled by models? Cumulus Parametrization!

CI trigger function in mass flux convection schemes tests each grid point by

- vertical velocity offset at LCL (= cloud base), Kuo 1965
- adding temperature offset depending on grid-scale vertical wind (large scale lifting supports CI), Fritsch and Chappel 1980
- height depending threshold of temp. offset, Kain 2003

- shallow/deep convection depending on range between LCL and LNB of the perturbed case (=extend of subgrid-scale cloud) precip. is turned on; typically 3 km

Presently used CI trigger functions are justified empirically!
Many modles trust on just a single parameter (e.g., COSMO with Tiedke 1989 uses offset to vertical wind only).

What do we need to investigate CI?

1. **Accurate data, especially of water vapor (lesson from, e.g., IHOP_2002)**

→ Intercomparisons, higher-order corrections to reach better than 5 % accuracy

2. IOP case studies

→ Investigate small scale heterogeneity of water vapor, temperature, wind, fluxes, boundary layer height, clouds, aerosols and their relation to CI

→ Combine simultaneous data of temperature and water vapor:

$d\theta/dz$, $d\theta_v/dz$, buoyancy, CAPE, CIN

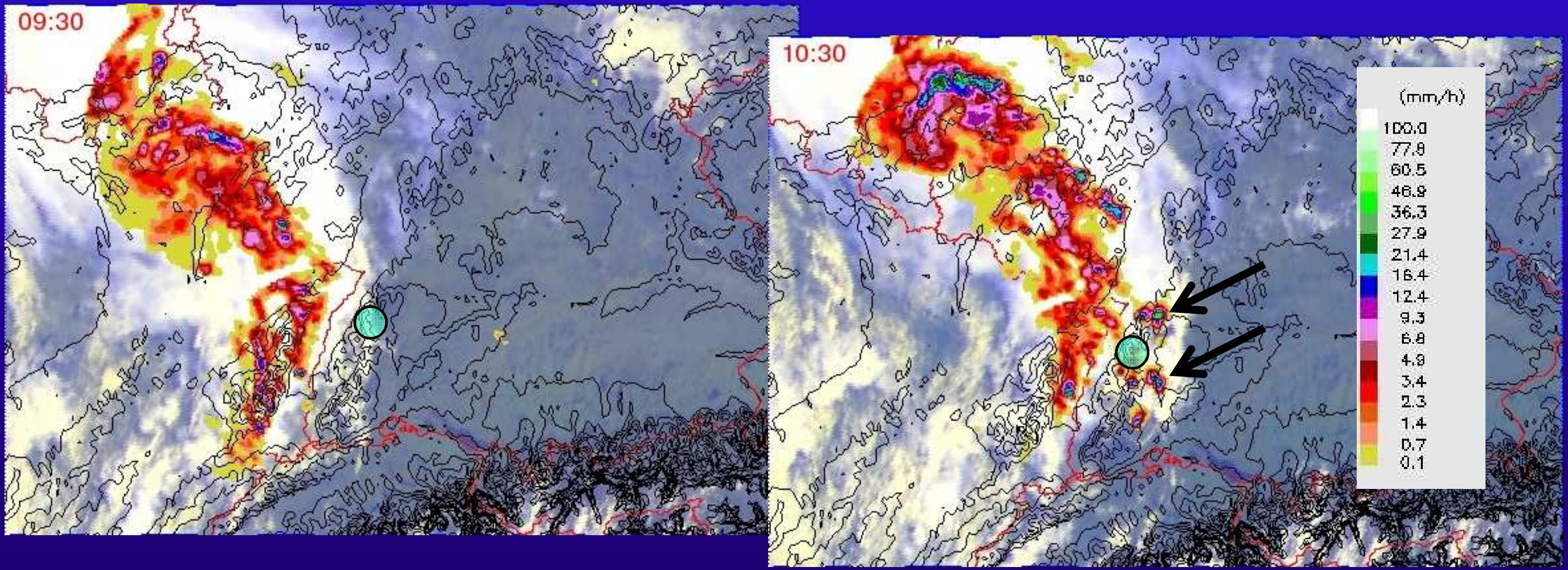
3. Comparison with different parameterization concepts

→ D-PHASE, COPS-GRID re-analyses, and hybrid convection schemes

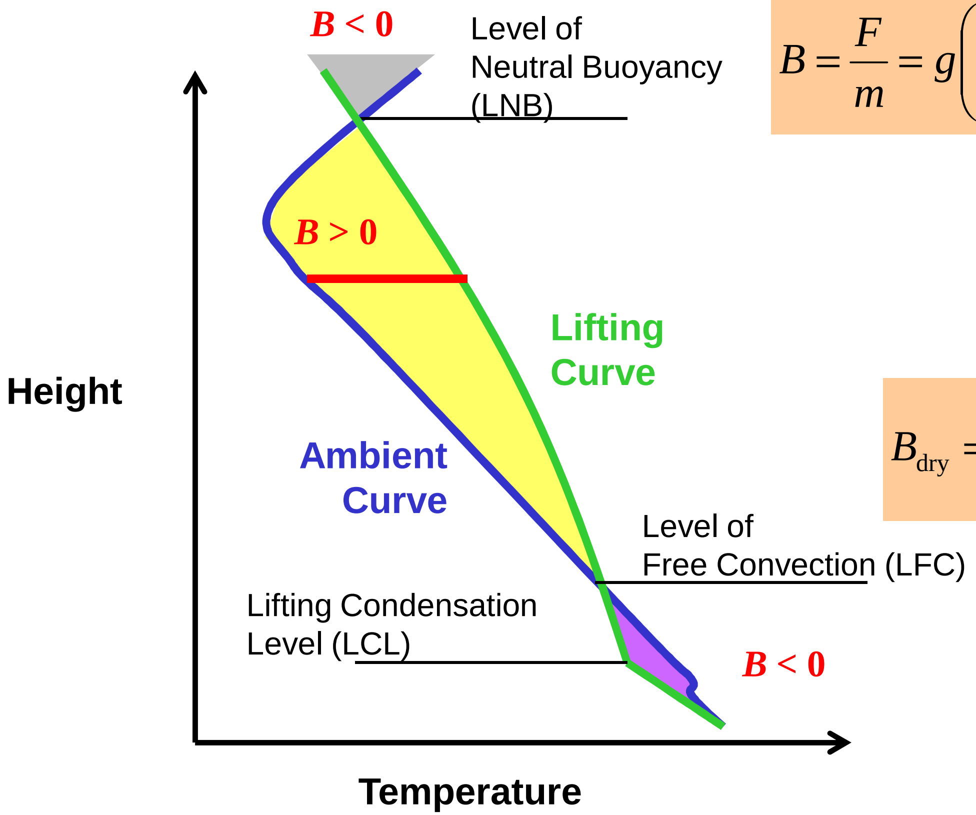
IOP 9c, 20 July 2009

- COPS IOP 9c: flooding, modification of front in Northern Black Forest, all COPS research instruments operated, „non-case“ on Hornisgrinde

  -> perfect conditions to measure pre-convective fields with lidars
- New product: 5-minute Buoyancy profiles of collocated rotational Raman lidar (*T*) and water vapor DIAL (& ground met station)
- Precison (stat. uncertainty) directly obtained from the signal intensities
- Differences to drifting radiosondes?



Buoyancy *B*



$$B = \frac{F}{m} = g\left(\frac{\rho_{\text{parcel}} - \rho_{\text{ambient}}}{\rho_{\text{ambient}}}\right) = g\left(\frac{\theta_{\text{virtual,parcel}} - \theta_{\text{virtual,ambient}}}{\theta_{\text{virtual,ambient}}}\right)$$

$$\theta_{\text{virtual}} = T\left(\frac{1000\text{ hPa}}{p}\right)^{0.286}(1 + 0.61\,r)$$

$$B_{\text{dry}} = g\left(\frac{\rho_{\text{parcel,dry}} - \rho_{\text{ambient,dry}}}{\rho_{\text{ambient,dry}}}\right) = g\left(\frac{\theta_{\text{parcel}} - \theta_{\text{ambient}}}{\theta_{\text{ambient}}}\right)$$

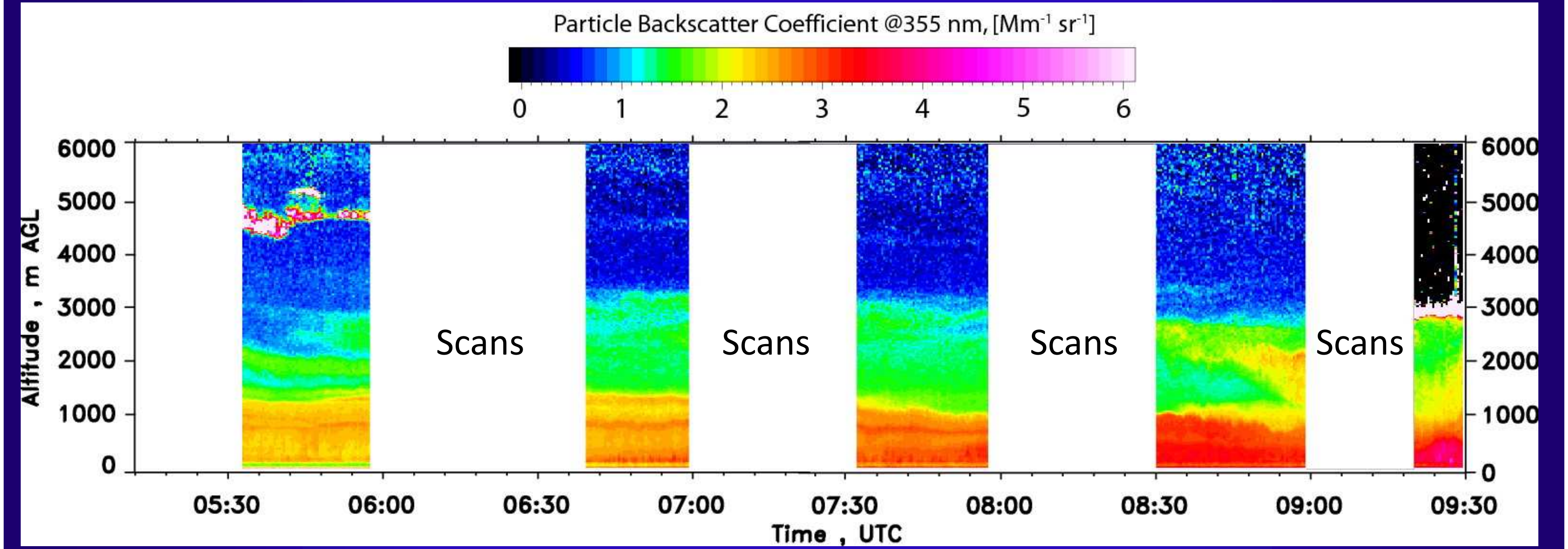
$$\theta = T\left(\frac{1000\text{ hPa}}{p}\right)^{0.286}$$

Ambient Curve: *T* and *r* from lidar

Lifting Curve: *T* and *r* from ground met station

Particles: UHOH Rotational Raman Lidar

20 July 2007, IOP 9c



$\Delta z = 3.75$ m
$\Delta t = 13$ s

Humidity: UHOH DIAL

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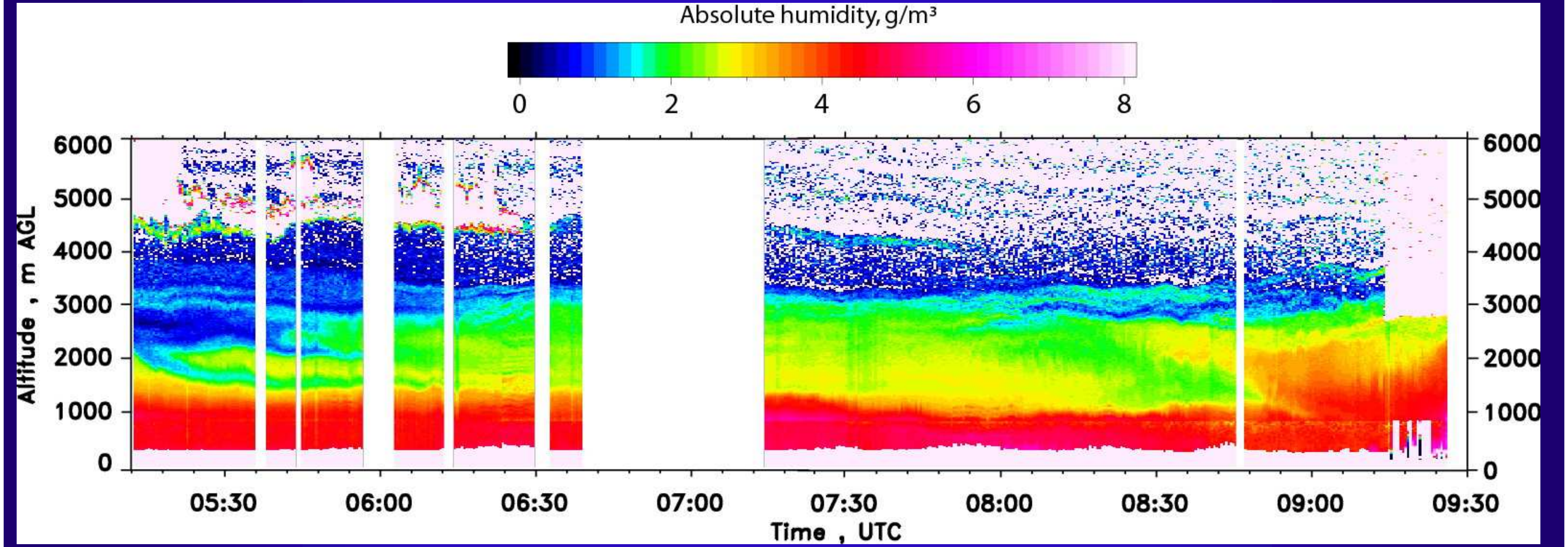

$\Delta z = 150$ m
$\Delta t = 10$ s

dθ/dz : UHOH Rotational Raman Lidar

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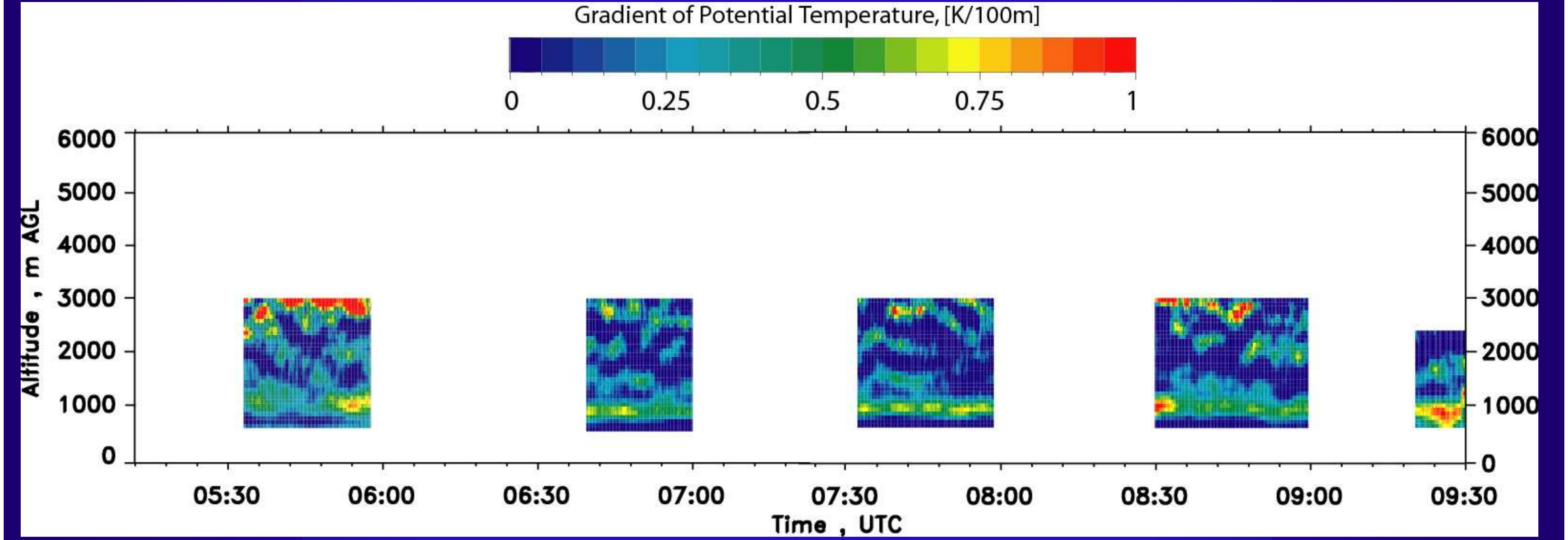
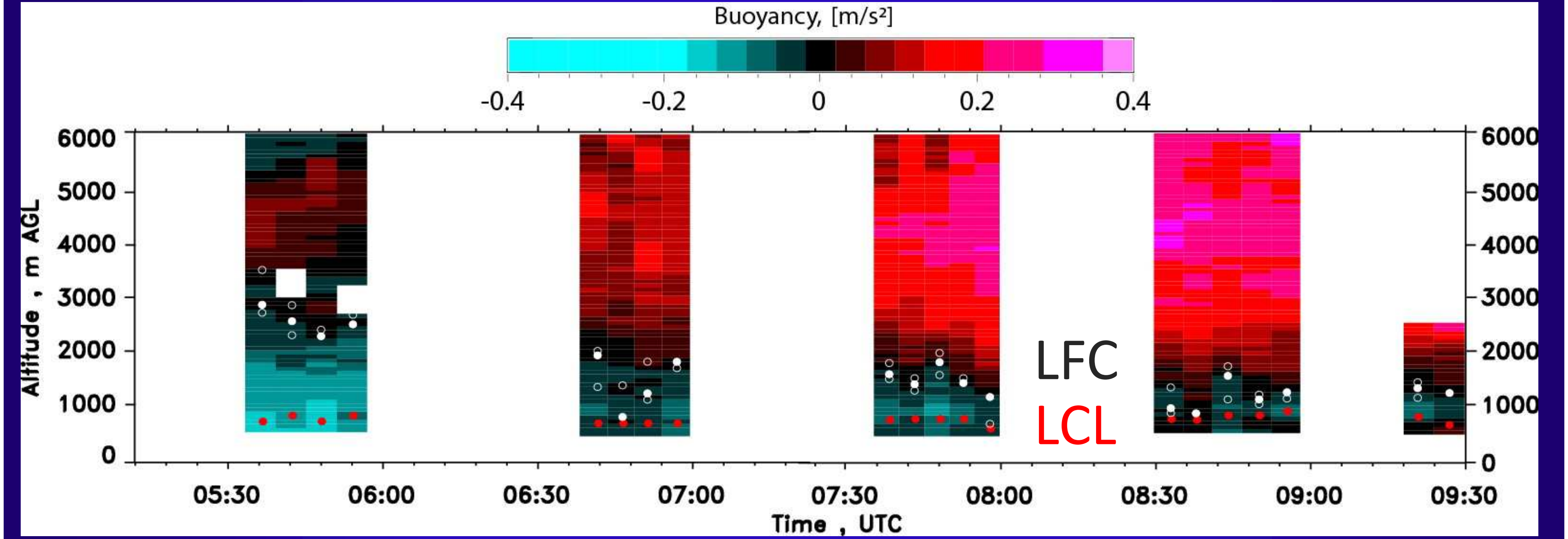


$$\theta = T\left(\frac{1000\ \text{hPa}}{p}\right)^{0.286}$$

Δz = 75 m
Δt = 3 min

„Dry“ Buoyancy: UHOH Rotational Raman Lidar

20 July 2007, IOP 9c

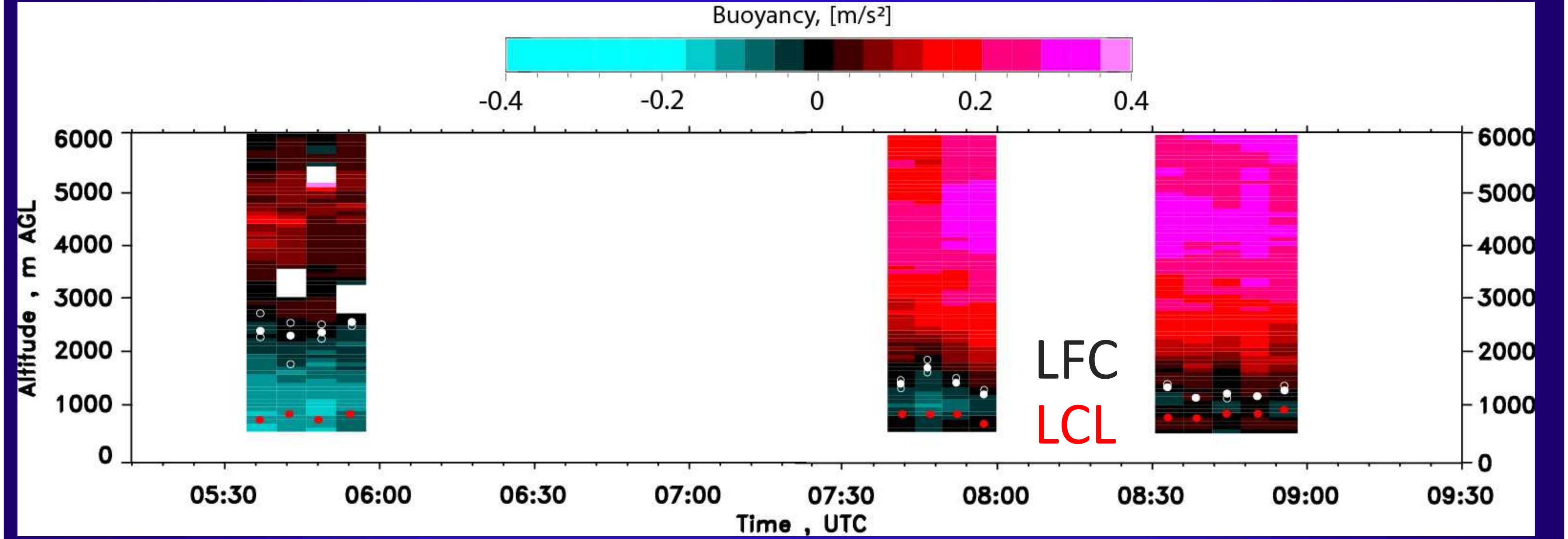


$$B_{\mathrm{dry}} = g\left(\frac{\theta_{\mathrm{parcel}} - \theta_{\mathrm{ambient}}}{\theta_{\mathrm{ambient}}}\right)$$

Δz = 150 m
Δt = 5 min

„Moist“ Buoyancy: UHOH RRL & DIAL

20 July 2007, IOP 9c



$$B = g\left(\frac{\theta_{\text{virtual,parcel}} - \theta_{\text{virtual,ambient}}}{\theta_{\text{virtual,ambient}}}\right)$$

Δz = 150 m
Δt = 5 min

What do we need to investigate CI?

1. **Accurate data, especially of water vapor (lesson from, e.g., IHOP_2002)**

→ Intercomparisons, higher-order corrections to reach better than 5 % accuracy

Lidar ✓
Radiosondes (✓)

Bhawar, Di Girolamo et al., Tue, 12:45
Bhawar, Di Girolamo et al., poster

2. IOP case studies

→ Investigate small scale heterogeneity of water vapor, temperature, wind, fluxes, boundary layer height, clouds, aerosols and their relation to CI

Ongoing at several groups

→ Combine simultaneous data of temperature and water vapor:

$d\theta/dz$, $d\theta_v/dz$, buoyancy, CAPE, CIN

Ongoing

3. Comparison with different parameterization concepts

→ D-PHASE, COPS-GRID re-analyses, and hybrid convection schemes

Outlook.